Hydro-Electric Power Commission

of the

Province of Ontario

REPORT

THE COST OF POWER PRODUCTION THROUGH THE AGENCY OF PRODUCER GAS PLANTS AND OTHER PRIME MOVERS UNDER THE CONDITIONS OBTAINING IN THE PROVINCE OF ONTARIO

HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

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ONTARIO.

COMMISSION

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To His Honour,

The Lieutenant-Governor of Ontario:

In accordance with the request of the Legislature of 1907, the undersigned Commissioners appointed by your Honour by Commission bearing date the 7th day of June, 1906, beg leave to submit the following report, as their report on the cost of power production through the agency of producer gas plants and other prime movers under conditions obtaining in the Province of Ontario.

Your Commissioners have made enquiries and obtained information from various sources, and the information obtained has been given freely to members of the engineering staff engaged upon the work, who have had instructions to go into the matter thoroughly and whose report has been made as complete as possible.

Your Commissioners have not given the names of their informants, but have used the knowledge and facts so acquired for the production of the results which they have now the honour to report.

The detailed tabulated and technical information has been tabulated and arranged by the Consulting Engineer employed by your Commissioners and approved by the Chief Engineer employed by your Commissioners, and the report of the Assistant Engineers employed by your Commissioners with reference to various producer gas plants throughout this country and the United States is submitted as an appendix hereto.

All of which is respectfully submitted,

(Sgd.) ADAM BECK,
Chairman,

JNO. S. HENDRIE,
W. K. MCNAUGHT.

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Honourable Adam Beck,
Chairman of the Hydro-Electric Power Commission:

DEAR SIR:—

Herewith please find the report on the cost of power production through the agency of producer gas plants and other prime movers under the conditions obtaining in the Province of Ontario.

The report deals more especially with the production of power through this prime mover and the results of tests obtained by our Engineers on individual plants.

Yours respectfully,

(Sgd.) P. W. SOTHMAN,
Chief Engineer.

TORONTO, March 2nd, 1908.

PART I.

In preparing this Report on the cost of power in the Province of Ontario, two considerations have led to the needs and requirements of the small consumer being specially kept in view. Firstly: Because as a whole, the small consumers probably use a larger amount of power than any other class of power users; and secondly, because every large power proposition is a problem in itself, and is therefore unsuited to the treatment necessary in a general report.

In considering this Report, it should be borne in mind that power is as much a manufactured commodity as any of the articles usually so described, and that the real cost of power to the consumer includes the cost of the raw material, an allowance to cover the cost of the machinery used in its manufacture, the cost of the labor expended on it, as well as the cost of transporting the power from the point at which the finished product is turned out (viz., at the engine shaft as B.H.P.), to the place where it is used.

This being a report on the costs of generating power, the costs shown in these estimates do not provide for its transmission, and the question of transmission is only referred to in order that a correct conclusion may be reached when the costs of power manufactured by the prime movers here considered are compared with the cost of other power, such as Hydro-Electric power, which includes in its price the cost of transmitting it and delivering it in a form suitable for use or further transmission.

The capital costs of the power installations as shown in these estimates are believed to be fair average costs applicable to power installations for manufacturing purposes, and the working expenses for an installation which is efficiently maintained, supervised and operated. The necessary plant to produce the power specified in some cases could doubtless be obtained at a less capital cost, but the result would usually be a less reliable service and greater operating cost. On the other hand a more reliable service and a smaller operating cost could be obtained by a larger capital expenditure and consequent increase in the fixed charges. Capital costs.

The choice of plant to be installed for power production and the

cost of installing and operating it depends on local conditions to an extent which makes it impossible to provide a general estimate which is likely to satisfactorily meet any specific proposition. The type of plant will differ with the situation in which it has to be installed, with the work required of it as well as the conditions under which the work has to be done. Price of fuel, price of labor, facility of water supply will also have a definite bearing on the plant chosen and for the same type the capital costs will vary according to the excellence and completeness of the plant installed, and these will again have an influence on working costs. The most expensive type of plant to install is a pressure or down draft producer gas plant,* followed in order of cost by suction gas plants,* steam plants, oil engines for use of kerosene oil, and gasoline engines; the cheapest being a gas engine for use with natural or illuminating gas.

The capital cost per B.H.P. installed will vary with the size of unit employed, larger units of the same type costing less per B.H.P. than smaller units. Generally speaking the units should be installed in the largest sizes that will admit of individual engines working at high load factors both to save in the capital cost of the unit itself and also in accessories such as land, buildings, boilers and condensing plant. These large units work more economically than smaller ones, and there is a saving not only in capital costs, but in fixed charges and working expenses.

Good quality in the plant will increase capital costs and consequently interest charges, but the total of the fixed charges will not be materially altered on this account as the increased interest charges will be compensated for by the less rate of depreciation and less cost of repairs, and in addition the user will obtain a more reliable service. The saving due to good quality of the plant will principally appear in the working charges owing to the smaller consumption of fuel and water, and less labor required.

Fixed charges.

The items taken to make up the fixed charges on the plant have probably been placed at a lower figure than conservative practice would dictate. It is doubtful if money to meet capital expenditure could to-day be obtained at 5% and so far as depreciation on producers and gas engines is concerned they have not been in existence long enough to enable a definite opinion to be given. In the estimates their depreciation has been figured as that of a steam engine and boiler, although it is quite common practice to figure depreciation 1%

*(NOTE.—Producer gas plants are comparatively new, and their costs have latterly been materially reduced, and there remains the possibility of some further reduction in this direction.)

higher in the case of gas plants, than in the case of equivalent steam, plants. On the other hand it is doubtful if many power users, particularly small power users, have any change made in the amount of their insurance or assessment, on account of their plant, although an allowance for such has been included under fixed charges in the estimates.

Working expenses consist principally of the cost of labor and fuel. In the case of small plants which do not require the whole of one man's time, it is impossible to make a general allowance for labor costs which will satisfy all cases, and, as in small plants of some types the cost of labor is the largest item in the cost of power, the choice of the type of plant to install will largely rest on the arrangements that can be made to employ the spare time of the attendant on other work. Working expenses.

In the estimates, for installations of small units, it has been considered that some such arrangement can be made and only the part time of an attendant has been charged to power production. If, however, the power user's circumstances are such that the time of the attendant cannot be divided between the plant and other work and the whole of his wages have to be charged to power production, the cost of power will considerably exceed that given in the estimate. It is partly for these reasons that in small plants the cost of power produced by gas, gasoline or oil engines is less than steam and producer gas plants which, although they work with less fuel costs, require more labor, which more than offsets the saving in fuel.

In large plants the position is reversed and the cost of fuel becomes more important than the cost of labor and the proper choice of fuel for use in the plant is essential for economic working, and with some types, particularly producer gas plants, it is essential to working at all. Although the value of coal to a power user depends on the heat units it contains it is seldom that this point is considered in purchasing it. Experiments recently made show that a steam plant required 3.66 lbs. of a coal averaging 13,621 heat units per pound to produce an electrical horse power hour, while an expenditure of 5.08 lbs. of a coal averaging 11,151 heat units per pound was required to produce a similar result in the same plant working under slightly more favorable conditions. Fuel costs.

Where coal is brought from a considerable distance, as it is in Ontario, it is usually advisable to use the grade of coal having the largest heat value per pound. At the mine the difference in heat values of two otherwise similar grades of coal may enable the mine owner to sell the coal having the largest heat value at a higher price, but the principal factor in the cost of coal to the user is the cost of transportation, and the difference in cost at the mine is only a small

fraction of the total cost when delivered, therefore the question of the heat value of the coal used as well as the price becomes important in selecting the grade, and merits more attention than is usually bestowed on it.

A comparison of the relative costs of producing power by the agency of various prime movers is often made on the basis of fuel costs only and usually on the assumption that the power plant will have an engine load factor of 100%. Such comparisons are usually misleading and always unworthy of consideration by a power user who desires to obtain his power service at the least total cost.

Many small plants designed to have a low fuel consumption are so expensive in first cost or require so much labor to operate, that a cheaper and simpler plant will produce power at a less total cost, although its fuel costs are comparatively large.

For example, a workshop requiring 10 B.H.P. as a maximum and working 10 hours a day with an average engine load factor of 50% will get its power for about 4.07 cts. per B.H.P. hour with a suction gas plant and 3.53 cts. per B.H.P. hour with a gas engine using illuminating gas, although the cost of coal for the suction gas plant would only be 0.42 cts against a cost of 2.25 cts. for the illuminating gas used in the gas engine. With a larger plant the conditions might be reversed. Thus if the above workshop required 30 B.H.P. as a maximum under the same conditions of load, the suction gas plant would deliver a B.H.P. hour at a total cost of 2.25 cts. against 2.82 cts. for an engine using illuminating gas, although the fuel cost would remain about the same, viz., 0.39 cts. and 2.03 cts. respectively. From this it will be seen that general statements regarding the cost of fuel for a particular type are not a sufficient basis on which to determine the plant to use. (Note Figures taken from Tables on Pages 35 and 74 et seq.)

The estimated costs of power, although comparable among themselves, being all on the same basis are not directly comparable with the cost of electric power sold on a meter basis. The cost of electric power at the meter or other point of delivery includes also the cost of transformation from brake horse-power to electrical horse-power and the cost of its transmission.

Therefore, in comparing the cost of power at the engine shaft, as given in the estimates, with electric power, bought as such, an addition to the cost per B.H.P. must be made to obtain the equivalent value of an E.H.P. This addition will usually be about 15%, as for this amount the power user could install the necessary electrical machinery and turn out his power in the form of electricity.

Unfortunately there is often a confusion of ideas which leads the power user to credit electricity, as a means of obtaining power, with the advantages which rightly belong to electricity, as a means of transmitting power. Savings in transmission.

It is commonly stated that, owing to the saving of transmission losses in the shafts and belting, electric power will reduce the total power consumption of a factory to one-half the power required with steam power, and the conclusion is drawn that the power user would be justified in paying nearly twice as much per E.H.P. hour for electric power as he would per B.H.P. for steam power.

This conclusion is in no way justified. If the power user installed a single electric motor to take the place of his steam engine, the power loss in the factory on account of transmission through the shafts and belts would remain the same, and the electric motor in delivering the same B.H.P. as the steam engine would require a greater E.H.P. at the meter, and would be more expensive. There is, therefore, no saving to the power user in using electric power where steam, gas or other power costs about the same, unless he alters his method of transmitting and using the power.

Should he wish to obtain the advantages of electricity for the transmission of the power in his factory and avoid the losses due to belts and shafting, he can do so by installing an electric generator in his own engine room, driven by his own engine, and obtain the same saving in transmission that he would obtain with bought electric power. An electric horse power obtained from his own plant would then cost him about 15% more than a B.H.P. similarly obtained, and, therefore, he is only justified in paying about 15% more for an E.H.P. than a B.H.P. instead of double, as often claimed.

This point is of considerable importance in discussing comparative power costs and cannot be neglected without vitiating the conclusions reached.

The cost of power has been calculated on the basis of a year of 3,000 working hours equivalent to 300 days of 10 hours each, and a year of 6,600 working hours equivalent to 300 days of 22 hours each, and for the plant working at various load factors. The year of 3,000 hours may be taken to represent fairly accurately the conditions in the average factory working from 7 a.m. to 6 p.m. with a noon interval of an hour. Time power is used.

The year of 6,600 hours will represent approximately the conditions obtaining in a factory which works day and night. The actual cost of power given in the estimate will usually be found low when compared with any specific proposition, because for the purpose of calculation it has been necessary to assume that there is the same load

on the machinery day and night; a condition that could obtain in but few cases. Furthermore, no allowance has been made for spare machinery in the estimates. This, in nearly every case, would be a necessity in order to prevent the inconvenience and loss that would be incurred from shut downs if it were attempted to run the plant for 24 hours a day, and the fixed charges on this spare plant would materially increase the cost of power as given in the estimates.

DEFINITIONS.

1. A watt is the amount of electrical power which is produced by one ampere flowing for one second at a pressure of one volt.
2. One kilowatt = 1,000 watts = 1.34 horse power.
3. One horse power = 746 watts = .746 kilowatts.
4. A British thermal unit is the amount of heat energy necessary to raise one pound of water one degree Fahrenheit.
5. One horse power developed for one hour will raise 2,545 lbs. of water one degree Fahrenheit = 2,545 B.T.U.
6. One kilowatt (1.34 horse power) will in one hour raise 3,412 pounds of water one degree Fahrenheit = 3,412 B.T.U.
7. *A theoretical horse power* is the amount of energy expended in moving a body one foot in one second against a resisting force of 550 pounds.
8. *An indicated horse power* (I.H.P.) is a measure of the work done in the cylinder of an engine.
9. *A brake horse power* (B.H.P.) is a measure of the energy delivered at the fly-wheel of an engine. For a given speed and a given load the brake horse power of an engine is less than the indicated horse power by the number of horse powers required to drive the engine without external load at the given speed, and with the same pressures on the guides, bearings, etc.
10. *An electrical horse power* (E.H.P.) is a measure of the energy delivered to the conducting wires by an electrical generator or to an electric motor by the conducting wires. If the generator be driven by an engine, then for a given load and a given speed, the electrical horse power of the generator will be less than the brake horse power of the engine by the number of horse powers lost in the coupling between engine and generator, and in the generator itself.

EXAMPLE: A gas engine which will develop 500 brake horse power is belted to an electrical generator. If the losses in the belt and generator amounted to 60 horse power the combination will develop 500 minus 60 = 440 electrical horse power. If the annual charges on this plant were 10,000 dollars, then the annual cost of one brake horse power would be $\frac{10000}{500}$ = \$20. On the basis of electrical horse power the annual cost of one horse power would be $\frac{10000}{440}$ = \$22.72.

PART II.

PRODUCER GAS PLANTS.

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PART II.

PRODUCER GAS PLANTS.

1. General Discussion.

In Ontario the field for producer gas plants for power production purposes will be found largely in those industries which do not use steam for heating or industrial purposes and which require power in medium quantities or require gas for brazing, annealing or tempering, or which have to work under drastic smoke nuisance by-laws. Within these somewhat narrow limits natural gas and hydro-electric power are likely to be its only serious competitors. From the power users' point of view, the saving in capital cost, reliability of operation, and simplicity of working obtainable from natural gas or hydro-electric power will allow these to enter into effective competition with producer plants, even when the cost of power so obtained is in excess of the cost of power developed by means of producer gas. Extent of use.

The situation of Ontario with regard to its coal supply and the present state of the art of designing producers for use with ordinary bituminous coal render it probable, for a considerable time to come, that the demand for producer gas plants will be met by the suction type using anthracite coal. Pressure or down-draft producers using bituminous coal are in successful operation in many places where it has been economically advisable to install them owing to the wide margin that obtains between the price of anthracite and bituminous coal or the very large size of the plant making the recovery of by-products from the gasification of bituminous coal profitable. These producers for bituminous coal are more complicated than suction producers and, requiring a steam boiler working under pressure, combine many of the objectionable features of steam plants with those of gas plants. These types use considerably more fuel than suction plants to accomplish the same useful work, require more supervision, and give less reliable service. To compensate for these disadvantages requires a greater margin between the cost of anthracite and bituminous coal than usually obtains in Ontario. In the future pressure and down draft producers will probably obtain their fullest development either in utilizing low grade fuels too poor in quality to be burnt under a boiler and too low in heat value to bear the cost of distant transportation in competition with better grade coals, or in countries where coal and wood are expensive and the only source of power. That is to say, under conditions which do not and are not likely to obtain in Ontario.

Pressure and down-draft producers, using the smaller sizes of anthracite, such as buckwheat and rice are in operation, and make a gas more suitable for use in an engine than those using bituminous coal, but the other objections to the use of these producers remain.

For instance, the National Board of Fire Underwriters require all pressure producer plants to be installed in a separate building, but this rule does not apply to suction producer plants until they are 250 H.P. and over.

Suction producers.

Suction producers can be worked on anthracite of pea size as usually sold in Ontario, and this grade has been used for the purposes of estimate. As it appears there is no standard specification for this grade of anthracite; the pea grade of some coal operators may be no better than smaller sized grades of other operators, and care must be taken that the pea grade of the local market is of suitable size and cleanness or the suction plant will not operate satisfactorily.

Good quality coke or charcoal will give as satisfactory a service as anthracite in suction producers, but will probably require 15% to 20% more by weight and a consequent increase in capital costs due to the larger producer required.

The principal merits of producer gas for power production are a small fuel consumption and for the present the absence of restrictive regulations such as apply to steam plants, and in some special cases the absence of smoke in working. The absence of restrictive regulations is not so much due to the inherent safety of this type of plant as to the lack of data on which to frame satisfactory regulations. The increasing number of accidents due to the poisonous and insidious nature of the gas generated is, however, leading to the formation and enforcement of such regulations, and with the increasing number of plants brought into use it is altogether probable that in time a trained and certified attendant will be as necessary in a gas plant as he now is in a steam plant.

Comparison with steam engine.

Compared with the steam engine or the electric motor the gas engine and, indeed, all internal combustion engines have the serious defect of having practically no capacity to take overloads or loads above their economic rating. A steam engine and an electric motor can be designed to run most economically at a certain loading, and to

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NOTE.—An exception to the statement that a suction-producer using anthracite is most suitable for use in Ontario may be made in the case of a manufacturer who has wood scrap as waste from his factory. It may so happen that this waste cannot be advantageously sold and is insufficient in quantity to produce the necessary power if burnt under a boiler. In such a case a producer using wood instead of coal might enable him to obtain his power from his waste product. Producers using wood instead of coal can be satisfactorily operated, but are not in general use as under ordinary circumstances coal is sufficiently cheap to displace wood.

take care of considerably greater loads for long periods of time, although at a lessened efficiency, which enables variable loads and over-loads to be handled with economy and a satisfactory service maintained. With the gas or any internal combustion engine its economic load is practically its maximum load, and its capacity to handle over-loads is very small. It therefore follows that with variable loads a gas engine has to have a capacity sufficient to handle maximum loads, although running the greater part of the time at an uneconomic loading.

Thus in a plant having an average load of 100 B.H.P., but occasionally reaching a maximum of 125 B.H.P., a steam engine of 100 B.H.P. would suffice, whereas a gas engine of 125 B.H.P. would be required to handle it satisfactorily. If a gas engine of 100 B.H.P. was installed to deal with a load of this sort, it would stop when the maximum load came on. This basic difference in the two types of engines should not be overlooked in comparing them. For non-fluctuating loads such as pumping into a reservoir they are fairly comparable on the basis of the power developed at their economic loading, but on a rapidly fluctuating load such as obtains in street railway work a gas engine of 125 or possibly 150 B.H.P. rating would be required to handle the same work that a 100 B.H.P. steam engine could easily take care of.

Difficulties in operation.

Similar to this inability of the gas engine to satisfactorily handle over-loads is its inability to start under a load, a failing which handicaps it considerably for certain classes of work, such as textile mill work, if the engine is connected directly to the shafting.

In many gas plants difficulties in starting, either from the engine refusing to start at all or starting in a backward direction, are so frequent as to cause considerable annoyance. The neglect of minor repairs and adjustments which in a steam engine would only result in a larger coal consumption while it continued to give the required service will in the case of a gas engine result in the engine refusing to work at all, a result which will also occur in producer plants if inattention to the producer causes any considerable variation in the quality of gas produced.

A considerable number of producer gas plants have been installed which have failed to give satisfaction and which in some cases have been superseded by steam plants or electric power. These failures are usually due to one of the following causes:—

1. The power consumer being persuaded to install a producer gas plant where this type is unsuited to the conditions of working.

2. Failure of the selling agents to have the plant properly erected and satisfactorily put to work before handing it over to the purchaser.
3. Failure of the selling agents and purchaser to arrange to have the attendant properly trained to work the producer plant before he is left in charge. It is practically impossible for an untrained man to run a producer plant satisfactorily.
4. Failure to obtain a suitable grade of coal for use in the producer.
5. The power user often buys the cheapest plant offered without reference to its reliability or efficiency, or he attempts to run his plant on the cheapest coal or with the cheapest labor.
6. Companies with no experience in producer or gas engine work take contracts for installing plant which they have never before manufactured or experimented with. Their experiments are then carried on at the expense of the purchaser, usually to his dissatisfaction.

Although the producer gas plant has not been long in commercial existence in this country as compared with other prime movers, there is no reason to anticipate that satisfactory results cannot be obtained with it where it is used within its proper limits. To insure these results, it is necessary that a producer plant be suited to the conditions under which it works, that the type is selected and the plant installed under the supervision of a competent person independent of the selling agents and that a trained man be placed in charge of it.

Almost every case of unsatisfactory service can be traced to a failure to observe one or the other of these rules. Unfortunately these requirements are more often more honored in breach than in observance and in practice the result is that producer gas plants have not substantiated the claims which their advocates have made for them.

A power user to-day would not be justified in investing in a producer gas plant unless the estimated saving in the total cost of power was sufficient to compensate him for an unreliable service. The producer gas plant compared to the steam plant is new, and the later plants give a more reliable service than the original types, so that in the future it may be anticipated that a type of producer gas plant will be evolved which will admit of comparison with the steam engine or electric motor on the basis of reliability under ordinary working conditions. An examination of a large number of plants for the purpose of this report has shown that the average reliability of the producer gas plant at present is not sufficient to admit of any comparison with that of the steam engine or electric motor.

2. Regulations of the National Board of Underwriters in Regard to the Installation and Operation of Producer-gas Plants.

1. Pressure Systems.—All pressure systems must be located in a special building or buildings approved for the purpose and at such distance from other buildings as not to constitute an exposure thereto.

2. Suction Systems.—(*a*) A suction gas-producer of approved make, having a maximum capacity not exceeding 250 h.p., may be located inside the building, provided the apparatus for producing and preparing the gas is installed in a separate, enclosed, well-ventilated, fire-proof room, with standard doors at all communicating openings.

The installation of gas-producers in cellars, basements, or any other places where artificial light will be necessary for their operation, is considered hazardous, and will not be permitted except by special permission of the underwriters having jurisdiction.

(*b*) The smoke and vent-pipe shall, where practicable, be carried above the roof of the building in which the apparatus is contained, and adjoining buildings, and when buildings are too high to make this practicable, the pipe shall end at least ten feet from any wall. Such smoke or vent-pipes shall not pass through floors, roofs, or partitions, nor shall they, under any circumstances, be connected into chimneys or flues.

(*c*) Platforms used in connection with generators must be of metal. Metal cans must be used for ashes.

(*d*) The producer and apparatus connected therewith shall be safely set on a solidly built foundation of brick, stone or cement.

(*e*) While the plant is not in operation the connection between the generator and scrubber must be closed, and the connection between the producer and vent-pipe opened, so that the products of combustion can be carried into the open air. This must be accomplished by means of a mechanical arrangement which will prevent one operation without the other.

(*f*) The producer must have sufficient mechanical strength to successfully resist all strains to which it will be subjected in practice.

(*g*) Wire gauze, not larger than sixty mesh or its equivalent, must be used in the test-pipe outlet in the engine-room.

(*h*) If illuminating or other pressure gas is used as an alternative supply, the connections must be so arranged as to make the mixing of the two gases, or the use of both at the same time impossible.

(*i*) Before making repairs which involve opening the gas passages to the air, the producer-fire must be drawn and quenched, and all combustible gas blown out of the apparatus through the vent-pipe.

(*j*) The opening for admitting fuel shall be provided with some charging device so that no considerable quantity of air can be admitted while charging.

(*k*) The apparatus must have name-plate giving the name of the device, capacity, and name of maker.

3. British Factory Act Regulations re Producer Gas Installations.

Form 827.

November, 1907.

FACTORY AND WORKSHOP ACT, 1901.

MEMORANDUM

AS TO THE

USE OF WATER GAS AND OTHER GASES IN FACTORIES.

Carbonic Oxide Poisoning.

In recent years there has been great extension of the manufacture and use of water gas and other gases of a similar nature (Dowson gas, Mond gas, Power gas, Producer gas, Blast furnace gas, Suction gas, etc.) for heating furnaces and boilers in factories, driving gas engines, welding, soldering, and many other industrial purposes. The particular danger associated with all these gases is that of poisoning by carbonic oxide (carbon monoxide, CO), which is also a constituent of ordinary coal gas. But whereas the proportion in coal gas varies from 4 to 12 per cent., in carburetted water gas it reaches 30 per cent., and in uncarburetted water gas 50 per cent. The other gases named above usually contain from 10 to 25 per cent.

The use of these gases was the subject of an inquiry in 1899 by a Departmental Committee,* who recommended in their report that the manufacture and distribution for heating and lighting purposes of any poisonous gas which does not contain a distinct and pungent smell should be prohibited, and that regulations should be made limiting the proportion of carbonic oxide. In recent Acts authorizing companies and local authorities to manufacture and supply Mond or similar gas for motive or heating purposes it is required that (1) the gas shall be strongly scented, and (2) either the quantity of carbonic oxide in the gas shall be limited to 14 per cent., or, when not so limited, the Secretary of State may impose such regulations as may be deemed necessary to protect against the risk of poisoning. It is

* Report of Water Gas Committee, 1899, on the Manufacture and Use of Gases containing a large proportion of Carbonic Oxide. C. 9164. Wyman & Sons, Ltd., Fetter Lane, E.C. Price, 1s. 2d.; by post, 1s. 5d.

made the duty of His Majesty's Inspectors of Factories to enforce these provisions as regards factories and workshops to which the gas is distributed.

The annual reports of the Factory Department during the seven years, 1899 to 1905, contain references to at least 108 cases, including 35 deaths, of poisoning by carbonic oxide on manufacturing premises. Of these 57 with 18 deaths have been reported in the last two years. This list does not include the slight cases of partial unconsciousness of which there is mention, entailing only a few hours' absence from work. These casualties were traced to several causes, among which may be mentioned:—(1) Leakage from joints or taps in pipes or flues conveying gas; (2) Gradual escape of gas into a small engine-room, weigh cabin, office, or the syphon-pit of the Dowson apparatus; (3) Cleaning and repairing of engines and of tanks, scrubbers, or blast furnace flues, before a sufficient time had been allowed for the gas to escape; (4) Inefficient disconnection from the blast furnace of the flue during cleaning; (5) Charging cupola furnaces at raised platforms; (6) Underground situation of flues and percolation of gas through several yards of soil; (7) Conveyance by the wind of gas escaping from defective reservoirs, or of waste gas allowed to blow off unburnt, through ventilators and open windows into workrooms at some distance from the gas generating plant; (8) Incomplete combustion of gas in defective gas ironing machines; (9) Ignorance of danger and of the earliest symptoms produced; (10) Inodorous nature of the gas; (11) Working alone; (12) Lack of rescue appliances.

Carbonic oxide poisoning may occur in other ways without inhalation of the particular gases named. Thus danger of this kind may arise in laundries from the use of gas irons, and in workrooms from defective gas fittings (especially absence of stop-pins or other appliances indicating the cutting off of gas) and from gas stoves, when no provision is made for the products of combustion to be carried away by a flue or chimney. The absence of a chimney in a room greatly increases the risk. Carbonic oxide is found also in lime kilns, cement works (see p. 32), and where braziers and coke fires are used in confined spaces.

Symptoms of carbonic oxide poisoning begin with throbbing of the blood vessels of the head, giddiness, palpitation of the heart and weakness of the limbs. These became greatly aggravated after any exertion. Owing to their insidious onset and the cumulative effect of the gas the weakness of the limbs may come on without attracting notice, so that the person affected is unable to make good his escape from the poisonous atmosphere.

Headache, anaemia, and defective nutrition may result from the long continued breathing of the gas in amount too small to produce immediate effects, such as might occur from defective gas fittings in work rooms.

The appropriate remedies for poisoning by carbonic oxide are—fresh air, artificial respiration, administration of oxygen and the application of warmth.

Preventive measures.—The precautionary measures to be considered must vary somewhat according to the different manner in which the gas is manufactured and used in one and another factory, but the following are of general application:—

1. Notices should be posted up stating the deadly nature of the gas, the symptoms produced by its inhalation, and the best means of rendering aid to those who are "gassed."*

2. Persons in charge of any engine worked by the gas, or of any apparatus in which it is stored, or otherwise exposed to risk of inhaling carbonic oxide, should be free from any disease of the heart or lungs. Employers would do well to cause such persons to be examined and certified by a medical man.

3. No person should be allowed single-handed to execute work in places where exposure to the gas is to be anticipated.

4. No engine in which the gas is used should be in a confined space.

5. A competent and responsible person should, at stated intervals, inspect all valves and connections, to see that there is no escape of gas; and a signed record with the dates of such inspections should be kept.

6. The openings giving access to any part of the gas circuit should be few, and in positions as safe as possible, and opened only in cases of real need and by responsible persons.

7. No workman should enter, or approach when opened, the holder or other part of the gas circuit until the gas has been well flushed out by fresh air.

8. A cylinder of compressed oxygen, fitted with a piece of rubber gas-tubing and a mouthpiece, should be kept in constant readiness. Such cylinders can be obtained fitted also with a reducing valve.

* See p. 30, where a form of such notice has been drawn up.

9. Medical aid should be summoned immediately, but in view of the importance of losing no time in commencing treatment, the workmen employed should be instructed by a medical man in the manner of administering the oxygen and of performing artificial respiration. They should be especially warned of the danger of exposing the patient to cold.

Respirators of the usual type designed to protect the wearer against inhalation of dust are of no avail as a protection against carbonic oxide poisoning.

When for purposes of rescue it becomes necessary to enter an atmosphere charged with the gas, the rescuer must protect himself by tying a rope securely round his waist, the free end being held by persons outside, or, preferably, by the use of one or other of the special rescue appliances designed for such work. The principle underlying them is that the rescuer is made to breathe air, or a mixture of air and oxygen, which renders him independent of the poisonous atmosphere immediately surrounding him. Such appliances are now kept in many chemical works, etc., and prominence has been given recently to certain types which, as in the Courrieres mining disaster, have proved their utility.

In towns where the public gas supply is largely charged with water gas, attention to gas fittings in factories and workshops becomes a matter of increased moment.

The following notice which has been drawn up by the Power Gas Corporation, Ltd., in consulation with the Medical Inspector of Factories, to be posted up near the place where danger arises, may serve as a model:—

DANGER OF GASSING.

Breathing of producer gas should be avoided. It is dangerous when breathed in quantity.

The first symptoms produced by breathing the gas are giddiness, weakness in the legs and palpitation of the heart.

If a man feels these symptoms, he should at once move into fresh, warm air, when in slight cases they will quickly disappear.

Exposure to cold should be avoided as it aggravates the symptoms.

A man should not walk home too soon after recovery, as muscular exertion after exposure to the gas is to be avoided.

If a man should be found insensible or seriously ill from the gas, he should at once be removed into fresh warm air, and immediate information be sent to the oxygen administrator, a medical man being sent for at the same time.

No man should work alone on any work which would be likely to involve exposure to the gas. Should the nature of the work cause the man to enter a culvert or hole, he should have a rope tied securely round his waist, held at the other end by his mate standing outside.

Use of the Oxygen Cylinder.

The cylinder should be provided with a lever key, nipple and union, together with a rubber tube at the end of which is a mouthpiece. It is also advisable to have a small pressure gauge attached to the cylinder so that loss of oxygen may be observed and the cylinder kept in working order.

Open the valve gradually by tapping the lever key (fully extended) with the wrist until the oxygen flows in a gentle stream from the mouthpiece in the patient's mouth, and allow the oxygen to be breathed until relief is obtained. The lips should not be closed round the mouthpiece, as it is important to allow free egress for surplus oxygen. The nostrils should be closed during inspiration or inflation of the lungs, and opened during expiration or deflation of the lungs, so that the oxygen may be inhaled as pure as possible through the mouth.

If the teeth are set, close the lips and one nostril. Let the conical end of the mouthpiece slightly enter the other nostril during inspiration and remove it for expiration.

Artifical Respiration.

Artificial respiration is sometimes necessary in addition to the oxygen inhalation if the oxygen does not appear to act quickly.

Place the patient on his back, slightly raising the shoulders with a folded coat; remove everything tight about the chest and neck; draw the tongue forward and maintain it in that position. Grasp the arms just above the elbows, and draw them steadily above the head, keeping them on the stretch for two seconds and then folding them and pressing them against the chest for the same length of time. Repeat these movements about fifteen times a minute for at least half an hour, or until natural breathing has been initiated, when the oxygen inhalation alone will suffice.

After recovery oxygen inhalation at intervals should be continued as desired.

Further detail may be needed in connection with particular branches of industry. Thus when one of a range of boilers in the firing of which waste blast furnace gas is used has to be disconnected for internal scaling and flue cleaning, the most necessary precautions

are that (1) the gas valve be shut as tight as possible and bolted in that position; (2) a special shutter should be used with its edges well cemented with wet clay to catch any possible leakage from the main valve; and (3) a man should always be stationed outside the boiler to give alarm in the event of no sound or answer coming from those inside.

In consequence of the constant danger of carbonic oxide poisoning in cement works, the Associated Portland Cement Manufacturers, Limited, have adopted the following notice in addition to somewhat similar instructions, to those given above:—

Regular inspection of kilns must be made on opening after being burnt off to see that they are safe for men to work in.

Under normal conditions the kiln is partly and sometimes drawn entirely before the chamber is cool enough to enter to clear for reloading, and inspection must cover safety, not only as to heat, but as to gases. The eye in front of kiln and back eye of chamber must be opened when drawing is commenced, and entrance to chamber must be made cautiously. Should there be the slightest indication of gas, a paper torch must be thrown into the kiln and seen to burn out properly before work therein is commenced. If after several attempts it is clearly shown that a paper torch will not burn freely, the men must not be allowed to enter, and the matter must be at once reported to the manager. This applies more particularly where there is a kiln burning next to one that is being drawn, but in any case the dampers of the kiln being drawn must be down tight, and precautions taken generally to see that fumes from a burning kiln on the same flue cannot get back into a kiln in which men are at work, and thus applies not only to the work of clearing or drawing, but to repair or any kind of work done in or about kilns.

In the case of a kiln which has lain cold for a long period, all the above-named precautions must be observed, and, in addition, before men enter the pan or chamber, the drawing eye of the kiln must be opened, and thoroughly freed below so that the air may pass into the charge. Employees are especially warned against adopting the means employed by many persons ignorant of the first principles of resuscitation, viz., placing men on their faces with mouth over a hole in the ground. All such means are strictly forbidden. The administration of stimulants in any form is most dangerous, and is also strictly forbidden.

(Sgd.) B. A. WHITELEGGE,
Chief Inspector of Factories.

Head Office, November, 1907.

ESTIMATES SHOWING THE COSTS OF INSTALLING AND WORKING SUCTION PRODUCER GAS PLANTS.

NOTE 1. The estimates are not for plant of any particular make, but represent the average cost of plant suitable for manufacturing purposes. No spare plant has been allowed.

2. Working costs have been based on the assumption of fairly steady loads and intelligent supervision. If the load fluctuates, fuel combustion and costs will increase, even though the average load remains the same. Unless skilled attendance is provided working costs will be considerably increased.

3. Fire insurance regulations will largely affect the cost of installing the plant and the cost of the buildings required. The costs given for these items will probably be found low for large towns.

4. Coal having about 13,500 B.T.U. per lb. has been assumed. Coal of a lesser heat value will require a larger quantity per B.H.P. hour, with a probable increased cost.

5. In plants of medium size or above it generally will be advisable to install two or more small units rather than one large one capable of taking the whole load.

6. Although units as large as 500 B.H.P. can be obtained and are working with suction producers and are therefore here estimated for, their use should not be decided on without very careful consideration.

SUCTION PRODUCER GAS PLANTS.

Size of Unit Installed in B. H. P.

CAPITAL COST.

	10	30	50	100	300	500
Plant, Engine, Producers, etc. ....(1)	$1,300.00	$2,100.00	$3,200.00	$6,200.00	$18,500.00	$27,600.00
Installation and Accessories. ....(2)	234.00	378.00	546.00	930.00	2,600.00	3,312.00
(1+2) TOTAL CAP. COST FOR MACHINERY. (3)	$1,534.00	$2,478.00	$3,746.00	$7,130.00	$21,100.00	$30,912.00
Engine Foundations....(4)	$ 33.00	$ 100.00	$ 160.00	$ 300.00	$ 850.00	$1,250.00
Building Coal Storage, Land, etc...........(5)	300.00	450.00	600.00	800.00	2,000.00	3,000.00
(4+5) TOTAL FOR BUILDINGS ....(6)	$333.00	$550.00	$760.00	$1,100.00	$2,850.00	$4,250.00
(3 + 6) GRAND TOTAL CAPITAL COSTS...(7)	$1,867.00	$3,028.00	$4,506.00	$8,230.00	$23,950.00	$35,162.00
Capital Costs per B.H.P...	$186.70	$100.93	$90.12	$82.30	$79.83	$70.32

FIXED CHARGES.

B.H.P. OF UNIT.	10	30	50	100	300	500
Int. on Capital invested, 5%..................	$ 93.35	$151.40	$225.30	$411.50	$1,197.50	$1,758.10
Dep. on Machinery, 6%...	92.04	148.68	224.76	427.80	1,266.00	1,854.72
Dep. on Buildings, 2%...	6.66	11.00	15.20	22.00	57.00	85.00
Fire Ins. 1%, Taxes 1½%; Total, 2½%	46.67	75.70	112.65	205.75	598.75	879.05
Repairs on Buildings, 2%..	6.66	11.00	15.20	22.00	57.00	85.00
TOTAL FIXED CHARGES	$245.38	$397.78	$593.11	$1,089.05	$3,176.25	$4,661.87

Working Expenses.

		10	30	50	100	300	500
MAINTENANCE AND REPAIRS ON MACHINERY.							
Year of 3,000 Hours......		$30.68	$49.56	$74.92	$142.60	$422.00	$618.24
Year of 6,600 Hours......		61.36	99.12	149.84	285.20	844.00	1,236.48
ATTENDANCE.							
Year of 3,000 Hours......		$260.00	$350.00	$400.00	$600.00	$1,000.00	$1,200.00
Year of 6,600 Hours......		520.00	700.00	800.00	1,200.00	2,000.00	2,400.00
COST OF ANTHRACITE COAL PER B.H.P. HOUR; AT $5.00 PER 2,000 LBS. DELIVERED.							
Ave. load on Engine in % of rated capacity	100%	1.25 lbs. .31c.	1.15 lbs. .29c.	1.05 lbs. .26c.	1.00 lbs. .25c.	1.00 lbs. .25c.	1.00 lbs. .25c.
	75%	1.45 lbs. .36c.	1.33 lbs. .33c.	1.25 lbs. .31c.	1.15 lbs. .29c.	1.15 lbs. .29c.	1.15 lbs. .29c.
	50%	1.70 lbs. .42c.	1.55 lbs. .39c.	1.40 lbs. .35c.	1.35 lbs. .34c.	1.35 lbs. .34c.	1.35 lbs. .34c.
COST OF LUBRICATING OIL, WASTE AND SUNDRIES, PER B.H.P. HOUR.							
Ave. load on Engine in % of rated capacity	100%	.06c.	.06c.	.05c.	.05c.	.05c.	.05c.
	75%	.07c.	.07c.	.06c.	.06c.	.06c.	.06c.
	50%	.08c.	.08c.	.07c.	.07c.	.07c.	.07c.

SUCTION PRODUCER GAS PLANTS—Continued.

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, YEAR OF 3,000 HOURS.

B.H.P. OF UNIT.	10	30	50	100	300	500
Fixed Charges	$ 245.38	$ 397.78	$ 593.11	$1,089.05	$3,176.25	$4,661.87
Maintenance and Repairs on Machinery	30.68	49.56	74.92	142.60	422.00	618.24
Attendance	260.00	350.00	400.00	600.00	1,000.00	1,200.00
Coal	93.00	261.00	390.00	750.00	2,250.00	3,750.00
Oil, Waste and Sundries	18.00	54.00	75.00	150.00	450.00	750.00
TOTAL COST PER YEAR	$647.06	$1,112.34	$1,533.03	$2,731.65	$7,298.25	$10,980.11
Cost per Year per B.H.P. of Average Demand	$64.70	$37.08	$30.66	$27.32	$24.33	$21.96
Cost per B.H.P. Hour	Cents. 2.16	Cents. 1.23	Cents. 1.02	Cents. .91	Cents. .81	Cents. .73
Cost per Year per B.H.P. of Rated Capacity	$64.70	$37.08	$30.66	$27.32	$24.33	$21.86

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, YEAR OF 6,600 HOURS.

B.H.P. OF UNIT.	10	30	50	100	300	500
Fixed Charges	$ 245.38	$ 397.78	$ 593.11	$1,089.05	$3,176.25	$4,661.87
Maintenance and Repairs on Machinery	61.36	99.12	149.84	285.20	844.00	1,236.48
Attendance	520.00	700.00	800.00	1,200.00	2,000.00	2,400.00
Coal	204.60	574.20	858.00	1,650.00	4,950.00	8,250.00
Oil, Waste and Sundries	39.60	118.80	165.00	330.00	990.00	1,650.00
TOTAL COST PER YEAR	$1,070.94	$1,889.90	$2,565.95	$4,554.25	$11,960.25	$18,198.35
Cost per Year per B.H.P. of Average Demand	$107.09	$63.00	$51.32	$45.54	$39.87	$36.40
Cost per B.H.P. Hour	Cents. 1.62	Cents. .95	Cents. .78	Cents. .69	Cents. .60	Cents. .55
Cost per Year per B.H.P. of Rated Capacity	$107.09	$63.00	$51.32	$45.54	$39.87	$36.40

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 3,000 HOURS PER YEAR.

B.H.P. OF UNIT.	10	30	50	100	300	500
Fixed Charges	$245.38	$ 397.78	$ 593.11	$1,089.05	$3,176.25	$4,661.87
Maintenance and Repairs on Machinery	30.68	49.56	74.92	142.60	422.00	618.24
Attendance	260.00	350.00	400.00	600.00	1,000.00	1,200.00
Coal	81.00	222.75	348.75	630.00	1,957.50	3,262.50
Oil, Waste and Sundries	15.75	47.25	67.50	135.00	405.00	675.00
TOTAL COST PER YEAR	$632.81	$1,067.34	$1,484.28	$2,596.65	$6,960.75	$10,417.61
Cost per Year per B.H.P. of Average Demand	$84.37	$47.43	$39.58	$34.62	$30.94	$27.43
Cost per B.H.P. Hour	Cents. 2.81	Cents. 1.58	Cents. 1.30	Cents. 1.15	Cents. 1.02	Cents. .96
Cost per Year per B.H.P. of Rated Capacity	$63.28	$35.58	$29.68	$25.96	$22.20	$20.61

SUCTION PRODUCER GAS PLANTS—Continued.

Yearly Costs, Engine Running 75% Rated Capacity, 6,600 Hours per Year.

Fixed Charges	$245.38	$397.78	$593.11	$1,089.05	$3,176.25	$4,661.87
Maintenance and Repairs on Machinery	61.36	99.12	149.84	285.20	844.00	1,236.48
Attendance (2 Shifts)	520.00	700.00	800.00	1,200.00	2,000.00	2,400.00
Coal	178.20	490.05	767.25	1,386.00	4,306.50	7,177.50
Oil, Waste and Sundries	34.65	103.95	148.50	297.00	891.00	1,485.00
Total Cost per Year	$1,039.59	$1,790.90	$2,458.70	$4,257.25	$11,217.75	$16,960.85
Cost per Year per B.H.P. of Average Demand	$138.61	$79.60	$65.56	$56.76	$49.85	$45.22
Cost per B.H.P. Hour	Cents. 2.10	Cents. 1.21	Cents. .99	Cents. .86	Cents. .76	Cents. .69
Cost per Year per B.H.P. of Rated Capacity	$103.96	$59.70	$49.17	$42.57	$37.39	$33.92

Yearly Costs, Engine Running 50% Rated Capacity, 3,000 Hours per Year.

B.H.P. of Unit.	10	30	50	100	300	500
Fixed Charges	$ 245.38	$ 397.78	$ 593.11	$1,089.05	$3,176.25	$4,661.87
Maintenance and Repairs on Machinery	30.68	49.56	74.92	142.60	422.00	618.24
Attendance	260.00	350.00	400.00	600.00	1,000.00	1,200.00
Coal	63:00	175.50	262.50	510.00	1,530.00	2,550.00
Oil, Waste and Sundries	12.00	36.00	52.50	105.00	315.00	525.00
Total Cost per Year	$611.06	$1,008.84	$1,383.03	$2,446.65	$6,443.25	$9,555.11
Cost per Year per B.H.P. of Average Demand	$122.12	$67.26	$55.37	$48.93	$42.96	$38.22
Cost per B.H.P. Hour	Cents. 4.07	Cents. 2.24	Cents. 1.84	Cents. 1.63	Cents. 1.43	Cents. 1.27
Cost per Year per B.H.P. of Rated Capacity	$61.06	$33.63	$27.68	$24.47	$21.48	$19.11

Yearly Costs, Engine Working 50% Rated Capacity, 6,600 Hours per Year.

Fixed Charges	$245.38	$ 397.78	$ 593.11	$1,089.05	$3,176.25	$4,661.87
Maintenance and Repairs on Machinery	61.36	99.12	149.84	285.20	844.00	1,236.48
Attendance	520.00	700.00	800.00	1,200.00	2,000.00	2,400.00
Coal	138.60	386.10	577.50	1,122.00	3,366.00	5,610.00
Oil, Waste and Sundries	26.40	79.20	115.50	231.00	693.00	1,155.00
Total Cost per Year	$991.74	$1,662.20	$2,235.95	$3,927.25	$10,079.25	$15,063.35
Cost per Year per B.H.P. of Average Demand	$198.34	$110.82	$89.46	$78.54	$67.12	$60.25
Cost per B.H.P. Hour	Cents. 3.01	Cents. 1.68	Cents. 1.35	Cents. 1.19	Cents. 1.02	Cents. .91
Cost per Year per B.H.P. of Rated Capacity	$99.17	$55.41	$44.73	$39.27	$33.56	$30.12

APPROXIMATE ALTERATION IN THE YEARLY COST PER AVERAGE B.H.P. DUE TO A CHANGE IN THE PRICE OF COAL OF 10 CENTS PER TON.

(It is assumed that the coal in each case will have the same heating value.)

NOTE 1.—To obtain the cost per B.H.P. hour due to a changed price of coal, correct the yearly cost per average B.H.P. as necessary, and divide by the number of working hours in the year.

NOTE 2.—To obtain the yearly cost per B.H.P. of rated capacity due to a changed price of coal, correct the yearly cost per average B.H.P. as necessary, and multiply by the load factor the plant is working on.

B. H. P. of Plant.	Load Factor.	Year of 3,000 Hours.	Year of 6,600 Hours.
10 B. H. P.	100%	$0.19	$0.41
	75%	.22	.49
	50%	.25	.55
30 B. H. P.	100%	.17	.37
	75%	.20	.44
	50%	.23	.49
50 B. H. P.	100%	.16	.34
	75%	.19	.41
	50%	.21	.46
100 B. H. P.	100%	.15	.33
	75%	.17	.37
	50%	.20	.45
300 B. H. P.	100%	.15	.33
	75%	.17	.37
	50%	.20	.45
500 B. H. P.	100%	.15	.33
	75%	.17	.37
	50%	.20	.45

TABULATED STATISTICS RELATING TO TWENTY-EIGHT PRODUCER GAS PLANTS VISITED BY THE COMMISSION'S ENGINEERS.

NOTE.—The data given is believed to correctly represent present-day results and has been based on information supplied by the firms using the plant. No attempt has been made to check this information.

Producer Gas Plants, Reference Number of Plant	10	H.E.P.C. Estimate	24	B	2	H.E.P.C. Estimate	E	D
Total Capacity B.H.P.	13	10	25	25	30	30	60	?
Size Units, B.H.P.	1 x 13	1 x 10	1 x 25	1 x 25	1 x 30	1 x 30	3 x 30	?
Units classed as Spares	Nil	Nil	Nil	Nil	Nil	Nil	Nil	?
Type of Producer	Suction	Suction	Suction		Suction	Suction	Suction	?
Location of Plant	U.S.A.	Ontario	U.S.A.	Canada	U.S.A.	Ontario	Canada	Canada
Cost Land and Buildings per B.H.P.	$[illegible]	$33.00	$[illegible]		Not known	$18.33	?	?
Cost Plant only, per B.H.P.	$[illegible]	$130.00	$[illegible]	$[illegible]	$[illegible]	$70.00	?	?
Cost Sundries per B.H.P.	Incl. in Plant	$23.40	Incl. in Plant	Incl. in Plant	Incl. in Plant	$12.60	?	FAILURE—Plant now Abandoned
TOTAL COST OF PLANT PER B.H.P.	$164.00	$186.70	$120.00		?	$100.93	$90.00	
Kind of Coal used	Pea Anth.	Pea Anth.	Pea Anth.		Pea Anth.	Pea Anth.	Pea Anth.	
Cost of Fuel per 2,000 lbs.	$[illegible]	$5.00	$[illegible]		$[illegible]	$5.00	$[illegible]	
Fuel consumption in lbs. per B.H.P.	[illegible]	1.45	[illegible]		[illegible]	1.33	1.54	
Cost of Fuel per B.H.P.	$[illegible]	$.0036	$[illegible]		$[illegible]	$.0033	$[illegible]	
Cost Attendance per B.H.P.	[illegible]	.0116	[illegible]	[illegible]	[illegible]	.0052	[illegible]	
Cost of Supplies per B.H.P.	[illegible]	.0021	[illegible]	FAILURE Plant now Abandoned	[illegible]	.0014	[illegible]	
Fixed Charges (Estimated) per B.H.P.	[illegible]	.0108	[illegible]		[illegible]	.0059	[illegible]	
TOTAL COST OF OPERATION PER B.H.P.	$.0217	$.0282	$0.0134		$.0144	$.0158	$.0164	
Load Factor	[illegible]	75%	[illegible]		[illegible]	75	[illegible]	
Average Working Hours per Year	[illegible]	3,000	[illegible]		[illegible]	3,000	[illegible]	
If Attendants give full time	No	No	No		No	No	No	
TOTAL COST OF ONE B.H.P. PER YEAR	$65	$85	$40		$42	$48	$49	

Producer Gas Plants, Reference Number of Plant	G	15	19	18	H.E.P.C. Estimate	F	1	8	9	5	H
Total Capacity B.H.P.	[illegible]	45	50	50	50	54	60	60	[illegible]	140	160
Size Units, B.H.P.	1 x 40	1 x 45	1 x 50	1 x 60	1 x 50	1 x 54	1 x 60	1 x 60	1 x 50 1 x 60	1 x 60 1 x 80	1 x 60 1 x 100
Units classed as Spares	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Type of Producer	Suction	Suction	Suction	Suction	Suction	Suction	Suction	Suction	Suction	Pressure	Suction
Location of Plant	Canada	U.S.A.	U.S.A.	U.S.A.	Ontario	Canada	U.S.A.	U.S.A.	U.S.A.	U.S.A.	Canada
Cost Land and Buildings per B.H.P.	?	$10.00	?	?	$15.20	?	Not known in detail	Not known	$12.00	$36	?
Cost Plant only, per B.H.P.	$[illegible]	$[illegible]	$[illegible]*	?	$64.00	$48.00		$[illegible]*	$[illegible]	$[illegible]*	?
Cost Sundries per B.H.P.	Incl. in Plant	Incl. in Plant	?	?	$10.92	?		Incl. in Plant	Incl.	Incl.	?
TOTAL COST OF PLANT PER B.H.P.	?	$99.00	?	?	$90.12	?	$83.00	?	$85.00	$171*	?
Kind of Coal used	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	B.W. Anth.	Coke
Cost of Fuel per 2,000 lbs.	$[illegible]	$[illegible]	$[illegible]	?	$5.00	$4.50	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]
Fuel consumption in lbs. per B.H.P.	[illegible]	[illegible]	[illegible]	FAILURE—Plant now Abandoned.	1.25	[illegible]	1.18	[illegible]	[illegible]	[illegible]	[illegible]
Cost of Fuel per B.H.P.	$[illegible]	$[illegible]	$[illegible]		$.0031	$.0030	$.0024	$[illegible]	$[illegible]	$[illegible]	$[illegible]
Cost Attendance per B.H.P.	[illegible]	.0012	[illegible]		.0036	[illegible]	.0071	.0058	.0040	[illegible]	[illegible]
Cost of Supplies per B.H.P.	.0013	.0018	.0043		.0012	.0008	.0012	.0013	.0008	.0004	.0009
Fixed Charges (Estimated) per B.H.P.	.0179	.0077	.0218		.0052	.0043	.0044	.0075	.0048	.0124	.0065
TOTAL COST OF OPERATION PER B.H.P.	$.0235	$.0156	$.0313		$.0130	$.0097	$.0151	$.0179	$.0128	$.0196	$.0115
Load Factor	[illegible]	[illegible]	[illegible]		75	[illegible]	70%	[illegible]	[illegible]	[illegible]	[illegible]
Average Working Hours per Year	3,000	3,100	2,800		3,000	3,300	4,000	2,800	2,800	3,000	3,000
If Attendants give full time	Yes	No	No		No	Yes	Yes	No	Yes	No	Yes
TOTAL COST OF ONE B.H.P. PER YEAR	$70	$48	$88		$39	$32	$60	$50	$36	$59	$35

Producer Gas Plants, Reference Number of Plant	C	17	A	16	6	12	7	26	H.E.P.C. Estimate
Total Capacity B.H.P.	80	75	150	[illegible]	85	89	[illegible]	200	100
Size Units, B.H.P.	?	1 x 75	2 x 75	[illegible]	1 x 85	1 x 89	2 x 100	2 x 100	1 x 100
Units classed as Spares	?	Nil	Nil	Nil	Nil	Nil	Nil	1 x 100	Nil
Type of Producer	?	Suction	Suction	Pressure	Pressure	Suction	Pressure	Suction	Suction
Location of Plant	Canada	U.S.A.	Canada	U.S.A.	U.S.A.	U.S.A.	U.S.A.	Canada	Ontario
Cost Land and Buildings per B.H.P.	?	?	?	Not known	$12.00	$10	$10.00	?	$11.00
Cost Plant only, per B.H.P.	?	?	$[illegible]		$[illegible]	$[illegible]*	$[illegible]*	?	$62.00
Cost Sundries per B.H.P.	?	?		[illegible]	Incl. in Plant	Incl.	Incl.	?	$9.30
TOTAL COST OF PLANT PER B.H.P.	$75.00	?	?	$103.00*	$102.00	$90*	$99.00*	$200.00*	$82.30
Kind of Coal used		Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	B.W. Anth.	Pea Anth.	Pea Anth.
Cost of Fuel per 2,000 lbs.	?	?	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$5.00
Fuel consumption in lbs. per B.H.P.	FAILURE—Plant now Abandoned.	FAILURE—Plant now Abandoned.	[illegible]	1.44	1.48	[illegible]	[illegible]	[illegible]	1.15
Cost of Fuel per B.H.P.			$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$.0029
Cost Attendance per B.H.P.			[illegible]	[illegible]	[illegible]	.0080	[illegible]	.0047	$.0026
Cost of Supplies per B.H.P.			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0012
Fixed Charges (Estimated) per B.H.P.			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0048
TOTAL COST OF OPERATION PER B.H.P.			$.0113	$.0088	$.0155	$.0200	$.0060	$.0150	$.0115
Load Factor			[illegible]	[illegible]	80%	[illegible]	[illegible]	[illegible]	75
Average Working Hours per Year			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3,000
If Attendants give full time			No	Yes		No	Yes	Yes	Yes
TOTAL COST OF ONE B.H.P. PER YEAR			$41	$62	$47	$60	$51	$122	$47

Producer Gas Plants, Reference Number of Plant	25	13	14	23	20	11	27	28
Total Capacity B.H.P.	125	175	[illegible]	150	250	[illegible]	200	580
Size Units, B.H.P.	1 x 125	1 x 50 1 x 125	1 x [illegible] 1 x 150	1 x 150	1 x 75 1 x 175	1 x 165 3 x [illegible]	1 x 200	1 x 250 3 x 90 1 x [illegible]
Units classed as Spares	Nil	1 x 50	1 x [illegible]	Nil	Nil	Nil	Nil	Nil
Type of Producer	Suction	Suction	Pressure	Suction	Pressure	Pressure	Suction	Pressure
Location of Plant	Canada	U.S.A.	U.S.A.	U.S.A.	U.S.A.	U.S.A.	Canada	Canada
Cost Land and Buildings per B.H.P.	$[illegible]	?	?	$8	?	Incl.	$[illegible]	$[illegible]*
Cost Plant only, per B.H.P.	$[illegible]	$[illegible]*	$74*	$[illegible]	$100	Incl.	$[illegible]*	$[illegible]*
Cost Sundries per B.H.P.	$[illegible]	Incl.	Incl.	$[illegible]	Incl.	Incl.	Incl. in Plant	Incl. in Plant
TOTAL COST OF PLANT PER B.H.P.	$100.00	?	?	$88	?	$120*	$88.00	$126.00*
Kind of Coal used	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	Pea Anth.	[illegible]	Pea Anth.	Pea Anth.
Cost of Fuel per 2,000 lbs.	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$4.80	$[illegible]
Fuel consumption in lbs. per B.H.P.	[illegible]	[illegible]	[illegible]	1.71	[illegible]	[illegible]	[illegible]	1.3
Cost of Fuel per B.H.P.	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$.0030
Cost Attendance per B.H.P.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0016
Cost of Supplies per B.H.P.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0005
Fixed Charges (Estimated) per B.H.P.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL COST OF OPERATION PER B.H.P.	$.0220	$.0168	$.0244	$.0195	$.0163	$.0147	$.0095	$.0091
Load Factor	[illegible]	42%	27%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average Working Hours per Year	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
If Attendants give full time	Yes	No	No	Yes	No	Yes	No	Yes
TOTAL COST OF ONE B.H.P. PER YEAR	$119	$47	$68	$55	$49	$44	$29	$66

NOTE.—The figures and letters shown as reference number of plant refer to plants reported on in the appendices.

* Prices marked * include Electric Generators and Switchboard Equipment.

PART III.

STEAM PLANTS.

1. *General discussion.*
2. *Estimates of the costs of installing and working steam plants.*

PART III.

STEAM PLANTS.

1. General Discussion.

The use of heat in many manufacturing processes and the necessity of heating buildings during a long winter, will in a large number of cases leave steam power in possession of the power field in Ontario even when its cost, referred to a power basis only, is in excess of the cost of power generated in producer gas plants or of hydro-electric power.

It is often stated that a steam plant using its exhaust steam for heating purposes supplies the heating without cost or vice versa. This is not entirely correct, as the power consumer to use his exhaust steam for heating has to forego the advantages that would be obtained by using condensers and thus either reducing his steam and fuel consumption or increasing the capacity of his plant. The value that these advantages would be to him is the cost of his heating, and although less than the cost that would be incurred by installing a separate heating system is yet sufficiently large to merit attention.

Taking the case of a steam plant with compound engines of 100 B.H.P. working condensing during the summer and using the whole of the exhaust steam for five months of the year for heating purposes, the fuel costs would be somewhat as follows, assuming the factory worked with an average load factor of 50%. Use of steam for heating.

Using the exhaust steam for heating five months a year:—

Coal required for 1,250 hrs. work, engines non-condensing and using 7 lbs.* coal per B.H.P. hour. .437,500 lbs.
Coal required for 1,750 hrs. work, engines condensed and using 5¾ lbs. coal per B.H.P. hour ....503,125 "
Total coal used per annum ....940,625 "

If, however, the engines were worked condensing the whole year and the boilers bled for steam for heating through a reducing valve directly into the steam heating system than the fuel expended would be.

Coal required for power purposes only for 3,000 hrs. per year, with the engines working condensing and using 5¾ lbs. coal per B.H.P. hour ......862,500 lbs.

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* ½ lb. coal extra on account of back pressure in the steam heating system.

Coal required for heating purposes for 1,250 hours (the coal used being 85% * of the amount before used for 5 months as above) .... 371,875 lbs.
Total coal used for heat and power purposes ......1,234,375 "

Showing a saving of 293,750 lbs of fuel in favor of using the exhaust steam for heating purposes, or a saving of about 24% of the fuel costs. The total saving will be larger than this by the amount which will cover attendance and fixed charges on a boiler for steam heating.

If in order to use the steam for heating purposes in winter only no condensing plant was installed, and the engine worked non-condensing throughout the year, for this purpose, then the saving would be smaller, amounting to only about 18.5% of the fuel cost instead of 24%.

Comparison with producer plants.

Comparing the cost of power and heating considered together for a non-condensing steam engine as shown in the estimates and a producer gas plant with separate heating system, both of 100 B.H.P. and a 50% load factor.

Cost of power for 3,000 hrs. steam plant using the exhaust steam for heating		$3,858.00
Cost of similar power from a producer gas plant	$2,446.65	
Cost of fuel for steam heating, 371,875 lbs., at $3.25 per ton	$ 604.30	
Allowance for attendance, fixed charges, etc., on boiler for steam heating	$ 450.00	
		$3,500.95
Saving in favor of producer plant		$ 357.05

or about 9% of the yearly charges for steam power, an amount which is considered insufficient to compensate the average steam user for the inherent disadvantages of a producer gas plant and even this small monetary advantage would be decreased if the steam plant used a condenser during the summer months.†

In small plants where the steam engines installed are usually uneconomical in steam consumption, producer gas plants will appear more favorably than they do in the above example, but as the majority of factories using steam for heating have plants of at least 100 B.H.P.

* 15% is allowed for condensation losses in the piping and cylinder losses which do not occur when the steam is taken directly from the boiler.

† (NOTE.—A comparison of this kind tends somewhat to a comparison on a full consumption basis. In this connection refer to p. 14, line 5 et seq.)

it may be accepted that with the present prices of coal the producer gas plant will not be able to compete seriously with steam plants where the exhaust steam is used for manufacturing or heating purposes, even where the engines are worked non-condensing for the whole year.

In large plants, especially those which have to deal with fluctuating loads, and which do not require steam for heating purposes, the steam turbine will enter into close competition with producer gas plants when considered on the basis of the total cost of power. The steam turbine plants will have the advantage, when considered on the basis of either capital costs or reliability of service. This case of the cost of power generation is not taken up in detail in this report as the station would be so large that it would be quite exceptional in Ontario.

As a general rule and so long as the present prices of coal do not materially increase, the steam driven plant may be expected to hold its present position, except in competition with cheap natural gas or hydro-electric power, in all cases where the exhaust steam can be used for heating or manufacturing purposes and in all power propositions of medium size or above, where a fluctuating load has to be taken care of. In plants requiring heat, natural gas and hydro-electric power will begin to compete with steam when the cost of power obtained by their agency is so low as to show sufficient savings over steam power to enable a separate heating system to be economically installed and worked, and under other conditions where heating is not an important question, when the costs based on B.H.P. are equal.

ESTIMATES SHOWING THE COSTS OF INSTALLING AND WORKING STEAM PLANTS.

NOTE 1. The estimates are not for plant of any particular make, but represent the average cost of a plant suitable for manufacturing purposes. No spare plant has been allowed.

2. It has been assumed that the water can either be obtained at a nominal cost or can be used in some other part of the factory, and therefore only a small allowance has been made for cooling water in the condensers.

3. Surface condensers have been assumed for the purpose of estimate. Jet or ejector condensers, if the conditions admitted their use would cheapen the capital cost of the installation.

4. No estimates have been prepared for steam turbines, as it has been considered that they are only likely to be suitable under present conditions in a small number of cases where a large amount of power is required.

5. Working costs have been based on the assumption of fairly steady loads and intelligent supervision. If the load fluctuates, fuel consumption and costs will increase, even though the average load remains the same. Unless skilled supervision is obtained, working costs will be considerably increased.

6. The plants of medium size and above it will usually be more satisfactory to provide two or more smaller units rather than one large unit.

STEAM PLANTS.

Capital Costs.

Type	Simple Non-condensing.	Simple Non-condensing.	Simple Non-condensing.	Compound Non-condensing.	Compound Condensing.	Compound Non-condensing.	Compound Condensing.	Compound Non-condensing.	Compound Condensing.
B.H.P. of Unit	**10**	**30**	**50**	**100**	**100**	**300**	**300**	**500**	**500**
Engines, Boilers, Piping, etc. (1)	$700.00	$2,160.00	$3,000.00	$5,500.00	$6,250.00	$12,750.00	$14,500.00	$20,000.00	$22,500.00
Installation and Accessories (2)	100.00	300.00	500.00	800.00	1,000.00	1,500.00	1,800.00	2,000.00	2,500.00
(1+2) Total Cost Machinery (3)	800.00	2,460.00	3,500.00	6,300.00	7,250.00	14,250.00	16,300.00	22,000.00	25,000.00
Engine Foundations, Boiler Setting, and Chimney (4)	100.00	675.00	1,060.00	1,300.00	1,500.00	3,000.00	3,400.00	4,750.00	5,250.00
Building, Coal Storage, and Load (5)	300.00	450.00	600.00	800.00	800.00	2,000.00	2,000.00	3,000.00	3,000.00
(4+5) Total Cost Building (6)	400.00	1,125.00	1,660.00	2,100.00	2,300.00	5,000.00	5,400.00	7,750.00	8,250.00
(3+6) Grand Total Capital Ac'nt (7)	1,200.00	3,585.00	5,160.00	8,400.00	9,550.00	19,250.00	21,700.00	29,750.00	33,250.00
Capital Costs per B.H.P.	120.00	119.50	103.20	84.00	95.50	64.17	72.33	59.50	66.50

Fixed Charges.

Interest on Capital, 5%	$ 60.00	$179.25	$258.00	$420.00	$477.50	$962.50	$1,085.00	$1,487.50	$1,662.50
Depreciation on Machinery, 6%	48.00	147.60	210.00	378.00	435.00	855.00	978.00	1,320.00	1,500.00
Depreciation on Buildings, 2%	8.00	22.50	33.20	42.00	46.00	100.00	108.00	155.00	165.00
Fire Ins. 1%, Taxes 1½%: Total 2½%	30.00	89.62	129.00	210.00	238.75	481.25	542.50	743.75	831.25
Repair of Building, 2%	8.00	22.50	33.20	42.00	46.00	100.00	108.00	155.00	165.00
Total Fixed Charges	$154.00	$461.47	$663.40	$1,092.00	$1,243.25	$2,498.75	$2,821.50	$3,861.25	$4,323.75

STEAM PLANTS.—Continued.

Working Expenses.

Type		Simple N.C.	Simple N.C.	Simple N.C.	Compound N.C.	Compound C.	Compound N.C.	Compound C.	Compound N.C.	Compound C.
B.H.P. of Unit		10	30	50	100	100	300	300	500	500
Maintenance and repair of machines	Year of 3,000 Hours	$16.00	$49.20	$70.00	$126.00	$145.00	$285.00	$326.00	$440.00	$500.00
	Year of 6,600 Hours	32.00	98.40	140.00	252.00	290.00	570.00	652.00	880.00	1,000.00
Attendance	Year of 3,000 Hrs.	500.00	600.00	700.00	900.00	900.00	1,300.00	1,300.00	1,500.00	1,500.00
	Year of 6,600 Hrs.	1,000.00	1,200.00	1,400.00	1,800.00	1,800.00	2,600.00	2,600.00	3,000.00	3,000.00

Coal, Bituminous Slack, at $3.25 per Ton (2,000 Lbs.). Delivered

Average Load on Engine in per cent. Capacity	100%	12 lbs. 1.95 c.	7 lbs. 1.14 c.	6½ lbs. 1.06 c.	5 lbs. .81 c.	4½ lbs. .73 c.	4 lbs. .65 c.	3¼ lbs. .53 c.	3½ lbs. .57 c.	3 lbs. .49 c.
	75%	14 lbs. 2.27 c.	8½ lbs. 1.38 c.	8 lbs. 1.30 c.	5¾ lbs. .93 c.	5¼ lbs. .85 c.	4½ lbs. .73 c.	3¾ lbs. .61 c.	4 lbs. .65 c.	3½ lbs. .57 c.
	50%	17 lbs. 2.76 c.	10 lbs. 1.62 c.	9 lbs. 1.46 c.	6½ lbs. 1.06 c.	5¾ lbs. .93 c.	5¼ lbs. .85 c.	4¼ lbs. .69 c.	4½ lbs. .73 c.	4 lbs. .65 c.

Lubricating Oil, Waste, Sundries, Water, Etc.

Average Load on Engine in per cent. of Capacity	100%	.16 c.	.10 c.	.10 c.	.08 c.	.08 c.	.06 c.	.06 c.	.05 c.	.05 c.
	75%	.20 c.	.13 c.	.12 c.	.09 c.	.09 c.	.07 c.	.07 c.	.06 c.	.06 c.
	50%	.24 c.	.16 c.	.15 c.	.10 c.	.10 c.	.08 c.	.08 c.	.07 c.	.07 c.

STEAM PLANTS—Continued.

Yearly Costs, Engine Running 100% Rated Capacity, 3,000 Hours per Year.

Type of Engine	Simp. N.C.	Simp. N.C.	Simp. N.C.	Comp. N.C.	Comp. C.	Comp. N.C.	Comp. C.	Comp. N.C.	Comp. C.
B.H.P. of Unit	10	30	50	100	100	300	300	500	500
Fixed Charges	$154.00	$ 461.47	$ 663.40	$1,092.00	$1,243.25	$2,498.75	$2,821.50	$3,861.25	$4,323.75
Attendance	500.00	600.00	700.00	900.00	900.00	1,300.00	1,300.00	1,500.00	1,500.00
Maintenance and Repairs on Machinery	16.00	49.20	70.00	126.00	145.00	285.00	326.00	440.00	500.00
Coal	585.00	1,026.00	1,590.00	2,430.00	1,190.00	5,850.00	4,770.00	8,550.00	7,350.00
Oil, Waste and Sundries	48.00	90.00	150.00	240.00	240.00	540.00	540.00	750.00	750.00
Total Cost per Year	$1,303.00	$2,226.67	$3,173.40	$4,788.00	$4,718.00	$10,473.75	$9,757.50	$15,101.25	$14,423.75
Cost per Yr. per B.H.P. of Av'ge Demand	$130.30	$74.22	$63.47	$47.88	$47.18	$34.91	$32.52	$30.20	$28.85
Cost per B.H.P. Hour	4.34 c.	2.47 c.	2.11 c.	1.59 c.	1.57 c.	1.16 c.	1.08 c.	1.01 c.	.96 c.
Cost per Yr. per B.H.P. of R'ted Capacity	$130.30	$74.22	$63.47	$47.88	$47.18	$34.91	$32.52	$30.20	$28.85

Yearly Costs, Engine Running 100% Rated Capacity, 6,600 Hours per Year.

Fixed Charges	$ 154.00	$ 461.47	$ 663.40	$1,092.00	$1,243.25	$2,498.75	$2,821.50	$3,861.25	$4,323.75
Attendance	1,000.00	1,200.00	1,400.00	1,800.00	1,800.00	2,600.00	2,600.00	3,000.00	3,000.00
Maintenance and Repairs on Machinery	32.00	98.40	140.00	252.00	290.00	570.00	652.00	880.00	1,000.00
Coal	1,287.00	2,257.20	3,498.00	5,346.00	4,818.00	12,870.00	10,494.00	18,810.00	16,170.00
Oil, Waste and Sundries	105.60	198.00	330.00	528.00	528.00	1,188.00	1,188.00	1,650.00	1,650.00
Total Cost per Year	$2,587.60	$4,215.07	$6,031.40	$9,018.00	$8,679.25	$19,726.75	$17,755.50	$28,201.25	$26,143.75
Cost per Yr. per B.H.P. of Av'ge Demand	$257.86	$140.50	$120.63	$90.18	$86.79	$65.75	$59.18	$56.40	$52.28
Cost per B.H.P. Hour	3.91 c.	2.13 c.	1.83 c.	1.36 c.	1.31 c.	0.99 c.	0.09 c.	0.85 c.	0.79 c.
Cost per Yr. per B.H.P. of R'ted Capacity	$257.86	$140.50	$120.63	$80.18	$86.79	$65.75	$59.18	$56.40	$52.28

STEAM PLANTS—Continued.

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 3,000 HOURS PER YEAR.

TYPE OF ENGINE	SIMP. N.C.	SIMP. N.C.	SIMP. N.C.	COMP. N.C.	COMP. C.	COMP. N.C.	COMP. C.	COMP. N.C.	COMP. C.
B.H.P. OF UNIT	**10**	**30**	**50**	**100**	**100**	**300**	**300**	**500**	**500**
Fixed Charges	$ 154.00	$ 461.47	$ 663.40	$1,092.00	$1,243.25	$2,498.75	$2,821.50	$3,861.25	$4,323.75
Attendance	500.00	600.00	700.00	900.00	900.00	1,300.00	1,300.00	1,500.00	1,500.00
Maintenance and Repairs on Machinery	16.00	49.20	70.00	126.00	145.00	285.00	326.00	440.00	500.00
Coal	510.75	931.50	1,462.50	2,092.50	1,912.50	4,927.50	4,117.50	7,312.50	6,412.50
Oil, Waste and Sundries	45.00	87.75	135.00	202.50	202.50	472.50	472.50	675.00	675.00
TOTAL COST PER YEAR	$1,225.75	$2,129.92	$3,030.90	$4,413.00	$4,403.25	$9,483.75	$9,037.50	$13,788.75	$13,411.25
Cost per Yr. per B.H.P. of Av'ge Demand	$163.43	$94.66	$80.83	$58.84	$58.72	$42.15	$40.16	$36.77	$35.75
Cost per B.H.P. Hour	5.45 c.	3.15 c.	2.69 c.	1.96 c.	1.96 c.	1.42 c.	1.34 c.	1.23 c.	1.19 c.
Cost per Yr. per B.H.P. of R'ted Capacity	$122.57	$70.99	$60.62	$44.13	$44.04	$31.61	$30.12	$27.58	$26.82

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 6,600 PER YEAR.

Fixed Charges	$ 154.00	$ 461.47	$ 663.40	$1,092.00	$1,243.25	$2,498.75	$2,821.50	$3,861.25	$4,323.75
Attendance	1,000.00	1,200.00	1,400.00	1,800.00	1,800.00	2,600.00	2,600.00	3,000.00	3,000.00
Maintenance and Repairs on Machinery	32.00	98.40	140.00	252.00	290.00	570.00	652.00	880.00	1,000.00
Coal	1,123.65	2,049.30	3,217.50	4,603.50	4,207.50	10,840.50	9,058.50	16,087.50	14,107.50
Oil, Waste and Sundries	99.00	193.05	297.00	445.50	445.50	1,039.50	1,039.50	1,485.00	1,485.00
TOTAL COST PER YEAR	$2,408.65	$4,002.22	$5,717.90	$8,193.00	$7,986.25	$17,548.75	$16,171.50	$25,313.75	$23,916.25
Cost per Yr. per B.H.P. of Av'ge Demand	$321.15	$177.87	$152.44	$109.24	$106.48	$77.99	$71.87	$67.50	$63.77
Yearly Cost per B.H.P.	4.86 c.	2.69 c.	2.31 c.	1.65 c.	1.61 c.	1.18 c.	1.09 c.	1.02 c.	0.97 c.
Cost per Yr. per B.H.P. of R'ted Capacity	$240.87	$133.41	$114.36	$81.93	$79.86	$58.49	$53.90	$50.62	$47.83

STEAM PLANTS—Continued.

Yearly Costs, Engine Running 50% Rated Capacity, 3,000 Hours per Year.

Type of Engine	Simp. N.C.	Simp. N.C.	Simp. N.C.	Comp. N.C.	Comp. C.	Comp. N.C.	Comp. C.	Comp. N.C.	Comp. C.
B.H.P. of Unit	10	30	50	100	100	300	300	500	500
Fixed Charges	$154.00	$461.47	$663.40	$1,092.00	$1,243.25	$2,498.75	$2,821.50	$3,861.25	$4,323.75
Attendance	500.00	600.00	700.00	900.00	900.00	1,300.00	1,300.00	1,500.00	1,500.00
Maintenance and Repairs on Machinery	16.00	49.20	70.00	126.00	145.00	285.00	326.00	440.00	500.00
Coal	414.00	729.00	1,095.00	1,590.00	1,395.00	3,825.00	3,105.00	5,475.00	4,875.00
Oil, Waste and Sundries	36.00	72.00	112.50	150.00	150.00	360.00	360.00	525.00	525.00
Total Cost per Year	$1,120.00	$1,911.67	$2,640.90	$3,858.00	$3,833.25	$8,268.75	$7,912.50	$11,801.25	$11,723.75
Cost per Yr. per B.H.P. of Av'ge Demand	$224.00	$127.44	$105.64	$77.16	$68.66	$55.12	$52.75	$47.20	$46.90
Yearly Cost per B.H.P. Hour	7.47 c.	4.25 c.	3.52 c.	2.57 c.	2.29 c.	1.84 c.	1.76 c.	1.57 c.	1.56 c.
Cost per Yr. per B.H.P. of R'ted Capacity	$112.00	$63.72	$52.82	$38.58	$38.33	$27.56	$26.37	$23.60	$23.45

Yearly Costs, Engine Running 50% Rated Capacity, 6,600 Hours per Year.

Fixed Charges	$ 154.00	$ 461.47	$ 663.40	$1,092.00	$1,243.25	$2,498.75	$2,821.50	$3,861.25	$4,323.75
Attendance	1,000.00	1,200.00	1,400.00	1,800.00	1,800.00	2,600.00	2,600.00	3,000.00	3,000.00
Maintenance and Repairs on Machinery	32.00	98.40	140.00	252.00	290.00	570.00	652.00	880.00	1,000.00
Coal	910.80	1,603.80	2,409.00	3,498.00	3,069.00	8,415.00	6,831.00	12,045.00	10,725.00
Oil, Waste and Sundries	79.20	158.40	247.50	330.00	330.00	792.00	792.00	1,155.00	1,155.00
Total Cost per Year	$2,176.00	$3,522.07	$4,859.90	$6,972.00	$6,732.25	$14,875.75	$13,696.50	$20,941.25	$20,203.75
Cost per Yr. per B.H.P. of Av'ge Demand	$435.20	$234.80	$194.39	$139.45	$134.65	$99.17	$91.31	$83.76	$80.82
Yearly Cost per B.H.P. Hour	6.59 c.	3.55 c.	2.94 c.	2.11 c.	2.04 c.	1.50 c.	1.38 c.	1.27 c.	1.22 c.
Cost per Yr. per B.H.P. of R'ted Capacity	$217.60	$117.40	$97.20	$69.72	$67.32	$49.58	$45.65	$41.88	$40.41

APPROXIMATE CORRECTION TO BE APPLIED TO THE COST PER YEARLY AVERAGE B.H.P. AS SHOWN IN THE ESTIMATES FOR STEAM ENGINES FOR EACH 10c. VARIATION IN THE PRICE OF COAL PER TON.

(It is assumed that the coal in each case will have the same heating value.)

NOTE 1.—To obtain the cost per B.H.P. hour due to a changed price of coal correct the yearly average cost per B.H.P. as necessary and divide by the number of working hours in the year.

NOTE 2.—To obtain the yearly cost per B.H.P. of rated capacity due to a changed price of coal; correct the yearly average cost per B.H.P. as necessary and multiply by the load factor the plant is working on.

B. H. P. of Unit and Type.	Load Factor.	Year of 3,000 Hours.	Year of 6,600 Hours.
10 B.H.P. Simple Non-condensing....	100% 75% 50%	$1.80 2.10 2.55	$3.96 4.62 5.61
30 B.H.P. Simple Non-condensing....	100% 5% 50%	1.05 1.28 1.50	2.31 2.82 3.30
50 B.H.P. Simple Non-condensing....	100% 75% 50%	.98 1.20 1.35	2.15 2.64 2.97
100 B.H.P. Comp. Non-condensing.....	100% 75% 50%	.75 .86 .98	1.65 1.89 2.16
100 B.H.P. Comp. Condensing.........	100% 75% 50%	.67 .79 .86	1.47 1.74 1.89
300 B.H.P. Comp. Non-condensing.....	100% 75% 50%	.60 .68 .79	1.32 1.50 1.74
300 B.H.P. Comp. Condensing.........	100% 75% 50%	.49 .56 .65	1.08 1.23 1.43
500 B.H.P. Comp. Condensing.........	100% 75% 50%	.53 .60 .67	1.17 1.32 1.47
500 B.H.P. Comp. Condensing.........	100% 75% 50%	.45 .53 .60	.99 1.17 1.32

PART IV.

OIL, GAS AND GASOLINE ENGINES.

1. *General discussion.*
2. *National Board of Underwriters' rules for the installation of gasoline engines.*
3. *Estimates of the cost of installating and working gasoline engines.*
4. *Regulations governing the installation of kerosene oil engines in large cities.*
5. *Estimates of the cost of installing and working kerosene oil engines.*
6. *Estimates of the cost of installing and working gas engines using illuminating gas.*
7. *Estimates of the cost of installing and working gas engines using natural gas.*

PART IV.

OIL AND GASOLINE ENGINES AND ENGINES USING ILLUMINATING OR NATURAL GAS.

1. General Discussion.

Power users who require power in small amounts as for workshop purposes or for short times at irregular intervals, as for agricultural purposes, will find their wants best supplied by small engines of the internal combustion type using coal oil, gasoline or gas, which require little or no labor in handling or preparation.

Although the fuel these engines use is of a somewhat expensive nature, their small capital cost and the little attention they need in working more than offset it, and their facility of starting without requiring a long time for preparation makes them especially suited to the requirements of power producers, who only require to use power occasionally.

Where gas is obtainable the gas engine will usually be found to give the most satisfactory service with the least first cost. Where gas is not available the choice will be between an engine using coal oil and an engine using gasoline.

Although the gasoline engine is somewhat cheaper in first cost, the oil engine is deserving of more attention than it usually obtains, as it gives as efficient a service as the gasoline engine with a less cost for fuel and uses a fuel which is more easily obtained. The insurance regulations which are stringent as to the use and storage of gasoline do not place the same restrictions on the use of coal oil.

Gas engines can be obtained up to any size likely to be required, and in many places where natural gas is obtainable, will generate power more cheaply and more satisfactorily than engines using producer gas.

Estimates are given for gas engines using natural gas of 980 B.T.U. per c. f., which enquiry shows is sold in Hamilton at 20 cents per 1,000 c.f., and nearer the wells could doubtless be obtained cheaper.

Although not estimated for in this report the alcohol engine will in the future occupy a place, so far as cost of power is concerned, between the gas engine using natural gas and the gas engine using illuminating gas. Nearly all countries at present impose a heavy tax on the manufacture of alcohol, even when it is to be used for industrial purposes. The high price of alcohol due to this tax has pre-

vented the alcohol engine being economically used and has retarded its development. With the removal of this tax on alcohol for industrial purposes; and legislation to effect this has been introduced, or is about to be introduced, in many countries; alcohol will be reduced to a fraction of its present price and the practically unlimited supply of alcohol that can be obtained at a low cost by the distillation of wood waste, corn stalks, etc., will permit of the alcohol engine taking a position in industrial life at least as important as that to-day occupied by the gas, gasoline and oil engine.

NATIONAL BOARD OF UNDERWRITERS' REGULATIONS REGARDING THE INSTALLATION AND USE OF GASOLINE ENGINES.

Rules and requirements of the National Board of Fire Underwriters for the installation and running of gasoline engines.

The Canadian Fire Underwriters' Association state that these rules also apply in Canada.

The rules for installation are as follows:

1. Location of Engines.

(*a*) Should, whenever possible, be located on the ground floor.

(*b*) In workshops or rooms where dust and inflammable flyings prevail, the engine to be enclosed in a fire-proof compartment well ventilated to the outer air at floor and ceiling.

(*c*) If located on a wooden floor the engine to be set on a metal plate turned up at the edges.

2. Supply Tank.

(*a*) Shall be located outside the building, underground, where possible, at least thirty feet removed from all buildings, and below the level of the lowest pipe in the building used in connection with the apparatus.

(*b*) If impracticable to bury the supply-tank, the same may be installed in a non-combustible building or vault properly ventilated, preferably from the bottom, always remembering that it must be below the level of the lowest pipe in the building used in connection with the apparatus.

(*c*) Auxiliary inside tanks, if used, shall not exceed one quart in capacity, and shall not be placed on, in, or under the engine, and shall be so arranged that when the supply-valve is closed a drain-valve into the return-pipe will be automatically opened. (See also paragraph 8, Note.)

3. Piping.

(*a*) None but tested pipe to be used.

(*b*) Connections to outside tank shall not be located near nor placed in the same trench with other piping.

(*c*) Openings for pipes through outside walls shall be securely cemented and made water and oil-tight.

(*d*) Piping to be run as direct as possible.

(*e*) Piping for gasoline-feed and overflow from auxiliary inside tank and feed-cup shall be installed with a good pitch so the gasoline will drain back to the supply-tank.

(*f*) Fill and vent-pipes leading to the surface of the ground shall be boxed or jacketed to prevent freezing of earth about them and loosening or breakage of connections.

4. Muffler or Exhaust-pot.

(*a*) Shall be placed on a firm foundation and be kept at least one foot from woodwork or combustible materials.

5. Exhaust-pipe.

(*a*) Exhaust-pipe, whether direct from engine or from mufflers, shall extend to the outside of the building, and be kept at least six inches from any woodwork or combustible material, and if run through floors or partitions shall be provided with ventilated thimbles.

(*b*) Shall in no case discharge into a chimney.

6. Care and Attention.

Due consideration shall be given the cleaning of the cylinder, valves, and exhaust pipe as often as the quality of the fuel may necessitate.

The rules for construction are as follows:

These rules are not to be considered as specifications for the shop construction of an engine, inasmuch as questions of design, efficiency, and operation are largely omitted. They cover only the outlines of construction of parts of special interest to the underwriters, and it should be noted that all engines conforming to the same are not of equal merit.

7. Outside Supply-tank.

(*a*) Must be constructed of iron or steel plate, securely riveted together or pressed into form. Tanks should be galvanized, or painted on the outside with rust-proof paint.

(*b*) Must be provided with a fill-pipe and a vent-pipe.

(*c*) The fill and vent-pipes to terminate in an iron box, cover of which should be flush with the ground, and locked with a padlock.

These pipes should be provided with screen near the top and the box to be properly ventilated.

8. Inside Auxiliary Tank.

Note: Auxiliary inside tanks with gravity feed are not advised as their use requires extra piping and fittings and an additional receptacle containing gasoline is introduced within the premises.

The gasoline feed-cup provided for below is sufficient for all ordinary purposes.

(*a*) Must not exceed one quart in capacity and must be constructed in an improved manner of brass or copper of at least No. 20 B. and S. gauge or else made in a casting.

(*b*) Must have no valves or plugs opening into the room with the exception of an air-vent.

(*c*) Must be provided with an overflow connection draining to the outside supply-tank.

9. Gasoline Feed-cup.

(*a*) Must be of cast metal rigidly secured to the engine-frame or mixing chamber, and must not exceed in capacity one-half pint.

(*b*) Must be provided with an approved controlling-valve or regulator.

(*c*) Must be arranged to prevent spattering, dripping, or exposure of gasoline during operation or with the engine at rest.

(*d*) Must be provided with an overflow connection draining to the outside supply-tank.

10. Gasoline Feed-pump.

(*a*) Should be of the simple single-plunger type with check-valve as close to the pump as convenient.

(*b*) No packing should be used on plunger or pump.

11. Igniter or Exploder.

(*a*) Electric ignition must be used.

12. Muffler or Exhaust-pot.

(*a*) Must be made equal in strength to the cylinder or other parts subject to effects of the explosion, and should be made in cylindrical or spherical form with as few joints as possible.

(*b*) Must be provided with a draw-off or drain-valve placed near the bottom and below the exhaust-pipe connection.

13. Valves.

(*a*) Shut-off valves must close against the gasoline supply, must be made of brass and have a stuffing-cap of liberal size arranged to force the packing against the valve-stem.

(*b*) No packing likely to be affected by gasoline to be used.

(*c*) Regulating valves, if not designed to close against the gasoline supply, or if used as a shut-off valve, must be provided with a special stuffing-cap having a follower-gland designed to hold and compress the packing.

Note: Engine-valves of the poppet type should preferably be so placed that gravity will act with spring to keep the valve closed.

14. Pipings and Fittings.

(*a*) Tank and drain-piping must be of brass or iron, not smaller than ⅜-inch size. Drain-pipe to be at least one size larger than supply-pipe.

(*b*) Connections by right and left couplings are advised in place of unions.

If unions are used they must be of brass, with a ground conical joint, obviating the use of packing or gaskets.

(*c*) A filter must be provided in the gasoline supply-pipe located near the engine and accessible for purpose of cleaning.

Note: A substantial flange-fitting containing fine brass gauze is recommended for use as a filter.

15. Engine Base.

(*a*) Must not be used as a storage space for gasoline or any other material.

(*b*) It is recommended that the base be constructed with a groove or channel to prevent lubricating oil from soaking into floors.

16. Lubricating Oil-drips and Pans.

(*a*) Must be provided where necessary to prevent the spilling of oil.

(*b*) Cranks and other rapidly revolving or reciprocating parts must be shielded to prevent throwing of oil.

17. Name-plate.

(*a*) Must be provided with a plate giving the name of the manufacturer, the trade-name of the engine, and its rated horse-power.

Other Fire Insurance Associations have the following rules:

Specifications to which all gasoline engines must conform in order to be approved for their installation:

1. Engines to be ignited by electric spark; tube-igniters not allowed.

2. Storage-tanks for gasoline shall be located underground, outside of the engine-room, and top of tank shall be below the level of the base of engine and not less than ten feet away from any building. Gasoline must be drawn from the general supply-tank, either to the engine, or the auxiliary or secondary reservoir or receptacle into which the pump discharges, and out of which the gasoline is fed into the engine. The overflow of said auxiliary or secondary reservoir or receptacle must lead back to the main storage-tank and be of four times the capacity of the pump.

3. Tanks to be cylindrical in shape and constructed as follows, viz., less than 200-gallon capacity to be of not less than 1/8-inch steel throughout. Tanks of 200 to 300-gallon capacity to be of not less than 3-16-inch steel throughout; heads to be stayed with iron; seams of all tanks to be securely riveted and caulked. Tanks to be coated with tar before being placed in the ground. No tank of larger than 300 gallons allowed.

4. Pipes leading from storage-tank to engine must be put together at every joint, metal to metal, with pipe screw connections. Supply and overflow-pipes to incline toward tank in order that surplus gasoline may drain back to tank from building when engine is not in operation; hand-valves to be placed in each supply and overflow-pipe outside of building, said valves to be closed when filling tank and when engine is shut down for the night. A vent provided with screw-cap must be attached to tank, said pipe to be open during filling. Storage-tank must be always filled by daylight, and all attachments between supply-wagon, tank-car, or barrels shall be tight-fitting screw-connections.

5. Any form of carbureter or vaporizer (that is, engines with a carbureter or vaporizer so constructed that by the passing of air over or through the gasoline the explosive mixture is formed within the carbureter or outside of the engine cylinder) is prohibited. This rule will apply except where vaporizer or carbureter has been specifically approved by this Association.

ESTIMATE SHOWING THE COSTS OF INSTALLING AND WORKING GASOLINE ENGINES.

NOTE 1. These estimates are not for plant of any particular make, but represent the average cost of plant suitable for manufacturing purposes. There is a considerable variation in the price of the smaller sized engines.

2. No spare plant has been allowed. Cost of providing storage for the gasoline has not been included.

3. Working costs have been based on the assumption of fairly steady loads and intelligent supervision. If the load fluctuates, fuel consumption and consequently working costs will increase even though the average load remains the same. Unless skilled attendance is provided the working costs will be considerably increased.

GASOLINE ENGINES.

Capital Costs.

B.H.P. of Unit	1½	5	10	30	50
Cost Complete (1) Installation and Accessories (2)	$150.00 25.00	$250.00 50.00	$420.00 75.00	$1,100.00 125.00	$1,800.00 200.00
(1+2) Total Capital Cost Mach. (3)	$175.00	$300.00	$495.00	$1,225.00	$2,000.00
Engine Foundations (4) Land and Buildings (5)	$15.00 75.00	$23.00 120.00	$ 33.00 200.00	$ 90.00 325.00	$160.00 450.00
Total Cost Land and Buildings (6)	$ 90.00	$143.00	$233.00	$415.00	$610.00
(3+6) Total Capital Costs (7)	$265.00	$443.00	$728.00	$1,640.00	$2,610.00
Cap. Costs per B.H.P.	$212.00	$88.60	$72.80	$54.67	$52.20 √

Fixed Charges.

B.H.P. of Unit	1½	5	10	30	50
Interest on Capital Cost, 5%	$13.25	$22.15	$36.40	$82.00	$130.50
Depreciation of Machinery, 6%	10.50	18.00	29.70	73.50	120.00
Depreciation on Buildings, 2%	1.80	2.86	4.66	8.30	12.20
Fire Ins. 1%, Taxes 1½%; Total 2½%	6.63	11.08	18.20	41.00	65.25
Repairs on Building, 2%	1.80	2.86	4.66	8.30	12.20
Total Fixed Charges	$33.98	$56.95	$93.62	$213.10	$340.15

Working Charges.

Maintenance and Repair of Mach.	3,000 hrs., 2%	$3.50	$ 6.00	$ 9.90	$24.50	$40.00
	6,600 hrs., 4%	7.00	12.00	19.80	49.00	80.00
Attendance	3,000 hrs.	30.00	60.00	90.00	120.00	140.00
	6,600 hrs.	60.00	120.00	180.00	240.00	280.00

Amount and Cost of Gasoline per B.H.P. Hour at 20 Cents per Gallon.

Average Load on Engine in % of Rated Capacity	100%	1.25 pts. 3.12 c.	1.17 pts. 2.93 c.	1.12 pts. 2.8 c.	1.00 pt. 2.5 c.	1.00 pt. 2.5 c.
	75%	1.4 pts. 3.5 c.	1.33 pts. 3.33 c.	1.27 pts. 3.17 c.	1.12 pts. 2.8 c.	1.12 pts. 2.8 c.
	50%	1.75 pts. 4.37 c.	1.55 pts. 3.88 c.	1.51 pts. 3.78 c.	1.40 pts. 3.5 c.	1.40 pts. 3.5 c.

Cost of Lubricating Oil, Waste, Sundries, Etc., per B.H.P. Hour.

Average Load on Engine in % of Rated Capacity	100%	.06 c.	.05 c.	.04 c.	.04 c.	.03 c.
	75%	.08 c.	.06 c.	.04 c.	.04 c.	.03 c.
	50%	.09 c.	.07 c.	.05 c.	.05 c.	.04 c.

GASOLINE ENGINES—Continued.

YEARLY COSTS, ENGINE WORKING AT 100% CAPACITY, 3,000 HOURS PER YEAR.

B.H.P. OF UNIT	1½	5	10	30	50
Fixed Charges	$ 33.98	$ 56.95	$ 93.62	$213.10	$340.15
Maintenance and Repairs	3.50	6.00	9.90	24.50	40.00
Attendance	30.00	60.00	90.00	120.00	140.00
Gasoline	117.00	439.50	840.00	2,250.00	3,750.00
Lubricating Oil, Waste and Sundries	2.25	7.50	12.00	36.00	45.00
TOTAL COST PER YEAR	$186.73	$569.95	$1,045.52	$2,643.60	$4,315.15
Cost per Year per B.H.P. of Average Demand	$149.20	$113.99	$104.55	$88.12	$86.30
Cost per B.H.P. Hour	4.97 c.	3.80 c.	3.48 c.	2.94 c.	2.87 c.
Cost per Year per B.H.P. of Rated Capacity	$149.20	$113.99	$104.55	$88.12	$86.30

YEARLY COSTS, ENGINE WORKING AT 100% CAPACITY, 6,600 HOURS PER YEAR.

Fixed Charges	$ 33.98	$ 56.95	$ 93.62	$213.10	$340.15
Maintenance and Repairs	7.00	12.00	19.80	49.00	80.00
Attendance	60.00	120.00	180.00	240.00	280.00
Gasoline	257.40	966.90	1,848.00	4,950.00	8,250.00
Lubricating Oil, Waste and Sundries	4.95	16.50	26.40	79.20	99.00
TOTAL COST PER YEAR	$363.33	$1,172.35	$2,167.82	$5,531.30	$9,049.15
Cost per Year per B.H.P. of Average Demand	290.66	234.47	216.78	184.38	180.98
Cost per B.H.P. Hour	4.40 c.	3.55 c.	3.28 c.	2.79 c.	2.74 c.
Cost per Year per B.H.P. of Rated Capacity	$290.66	$234.47	$216.78	$184.38	$180.98

YEARLY COSTS, ENGINE WORKING AT 75% CAPACITY, 3,000 HOURS PER YEAR.

B.H.P OF UNIT	1½	5	10	30	50
Fixed Charges	$33.98	$ 56.95	$ 93.62	$213.10	$340.15
Maintenance and Repairs	3.50	6.00	9.90	24.50	41.00
Attendance	30.00	60.00	90.00	120.00	140.00
Gasoline	98.44	374.63	713.25	1,890.00	3,150.00
Lubricating Oil, Waste and Sundries	2.25	6.75	9.00	27.00	33.75
TOTAL COST PER YEAR	$168.17	$504.33	$915.77	$2,274.60	$3,703.90
Cost per Year per B.H.P. of Average Demand	$179.38	$134.49	$122.10	$101.09	$98.80
Cost per B.H.P. Hour	5.98 c.	4.48 c.	4.07 c.	3.37 c.	3.29 c.
Cost per Year per B.H.P. of Rated Capacity	$134.53	$100.87	$91.58	$75.82	$74.08

GASOLINE ENGINES—Continued.

Yearly Costs, Engine Working at 75% Capacity, 6,600 Hours per Year.

Fixed Charges	$ 33.98	$ 56.95	$ 93.62	$213.10	$340.15
Maintenance and Repairs	7.00	12.00	19.80	49.00	80.00
Attendance	60.00	120.00	180.00	240.00	280.00
Gasoline	216.56	824.18	1,569.15	4,158.00	6,930.00
Lubricating Oil, Waste and Sundries	4.95	14.85	19.80	59.40	74.25
Total Cost per Year	$322.49	$1,027.98	$1,882.37	$4,719.50	$7,704.40
Cost per Year per B.H.P. of Average Demand	$343.99	$274.13	$250.98	$209.76	$205.45
Cost per B.H.P. Hour	5.21 c.	4.15 c.	3.80 c.	3.18 c.	3.11 c.
Cost per Year per B.H.P. of Rated Capacity	$257.99	$205.60	$188.24	$157.32	$154.09

Yearly Costs, Engine Working 50% Capacity, 3,000 Hours per Year.

B.H.P. of Unit	1¼	5	10	30	50
Fixed Charges	$33.98	$ 56.95	$ 93.62	$213.10	$340.15
Maintenance and Repairs	3.50	6.00	9.90	24.50	40.00
Attendance	30.00	60.00	90.00	120.00	140.00
Gasoline	81.94	291.00	567.00	1,575.00	2,625.00
Lubricating Oil, Waste and Sundries	1.69	5.25	7.50	22.50	30.00
Total Cost per Year	$151.11	$419.20	$768.02	$1,955.10	$3,175.15
Cost per Year per B.H.P. of Average Demand	$241.80	$167.68	$153.60	$130.34	$127.00
Cost per B.H.P. Hour	8.09 c.	5.59 c.	5.12 c.	4.34 c.	4.23 c.
Cost per Year per B.H.P. of Rated Capacity	$120.90	$83.84	$76.80	$67.17	$63.50

Yearly Costs, Engine Working 50% Capacity, 6,600 Hours per Year.

Fixed Charges	$ 33.98	$ 56.95	$ 93.62	$213.10	$340.15
Maintenance and Repairs	7.00	12.00	19.80	49.00	80.00
Attendance	60.00	120.00	180.00	240.00	280.00
Gasoline	180.26	640.20	1,247.40	3,465.00	5,775.00
Lubricating Oil, Waste and Sundries	3.72	11.55	16.50	49.50	66.00
Total Cost per Year	$284.96	$840.70	$1,557.32	$4,016.60	$6,541.15
Cost per Year per B.H.P. of Average Demand	$455.94	$336.28	$311.46	$267.77	$261.65
Cost per B.H.P. Hour	6.91 c.	5.10 c.	4.72 c.	4.06 c.	3.96 c.
Cost per Year per B.H.P. of Rated Capacity	$227.97	$168.14	$155.73	$133.89	$130.82

APPROXIMATE ALTERATION IN THE YEARLY COST PER AVERAGE B.H.P. DUE TO A CHANGE IN THE PRICE OF GASOLINE OF 1 CENT PER GALLON.

NOTE 1.—To obtain the cost per B.H.P. hour with a different price of gasoline, correct the yearly average cost as required and divide by the number of working hours in the year.

NOTE 2.—To obtain the yearly cost per B.H.P. of rated capacity on account of a different price of gasoline, correct the yearly cost per average B.H.P. as necessary, and multiply by the load factor the plant is working on.

B.H.P. of Unit.	Load Factor.	Year of 3,000 Hours.	Year of 6,600 Hours.
1¼	100%	$4.68	$10.30
	75%	5.25	11.55
	50%	6.57	14.45
5	100%	4.38	9.64
	75%	4.98	10.96
	50%	5.82	12.80
10	100%	4.20	9.24
	75%	4.76	10.47
	50%	5.68	12.50
30	100%	3.75	8.25
	75%	4.20	9.24
	50%	5.26	11.57
50	100%	3.75	8.25
	75%	4.20	9.24
	50%	5.26	11.57

INSURANCE REGULATIONS FOR KEROSENE OR COAL-OIL ENGINES.

The following are the requirements of the New York Board of Fire Underwriters for the installation and use of kerosene-oil engines, where gasoline engines are prohibited. Similar regulations would probably apply to Canada. The prospective user should, however, ascertain the local regulations before deciding on type to use.

Location of Engine.

Engine shall not be located where the normal temperature is above 95 degrees F., or within ten feet of any fire.

If enclosed in room, same must be well ventilated, and if room has a wood floor, the entire floor must be covered with metal and kept free from the drippings of oil.

If engine is not enclosed, and if set on a wood floor, then the floor under and three feet outside of it must be covered with metal.

Feed Tank.

If located inside the building, shall not exceed five gallons in capacity, and must be made of galvanized iron or copper, not less than No. 22 B. and S. gauge, and must be double seamed and soldered, and must be set in a drip-pan on the floor at the base of the engine.

Tanks of more than five-gallon capacity must be made of heavy iron or steel, be riveted, and be located, preferably, underground outside of the building. If there is no space available outside the building for a tank, it may, by written permission from this Board, be located in an approved vault attached to the building, or in a non-combustible and well-ventilated compartment inside the building, but no such tank shall exceed five barrels capacity.

Tanks, irrespective of the method of feed, must not be located above the floor on which the engine is set.

The base of an engine must not be used in lieu of a tank as a receptacle for feed-oil. A tank, if satisfactorily insulated from the heat of the engine, and approved by the Board, may be placed inside of the base. Some engines have the base arranged as a tank, and this should be enquired into before purchasing.

In starting an engine, gas only, properly arranged, must be used to heat the combustion chamber. Many engines are arranged to be heated by an oil blow lamp.

A high-grade kerosene oil must be used, the flash test of which shall be not lower then 100 degrees F.

Oily waste and rags must be kept in an approved self-closing metal can, with legs to raise it six inches above the floor.

The supply of oil, unless in an approved tank outside the building, or in a non-combustible compartment, as above on the premises, provided same is kept in an unexposed location ten feet distant from any fire, artificial light, and inflammable material, and oil drawn by daylight only.

A drip-pan must be placed under the barrel.

Empty kerosene barrels must not be kept on the premises.

ESTIMATES SHOWING THE COSTS OF INSTALLING AND WORKING ENGINES USING KEROSENE OIL.

NOTE 1. No provision for the storage of oil has been made in the estimates.

2. Oil engines are made in larger sizes than shown in the estimates, but it is not considered that they could be economically used in Ontario.

3. Working costs have been based on the assumption of fairly steady loads and intelligent supervision. If the load fluctuates oil consumption and costs will increase even though the average load remains the same.

4. Engines using less oil than those shown in the estimates are obtainable, but at an increased cost. As they require considerable skill in operation they have been considered unsuitable for use in Ontario and have not been estimated for.

5. The estimates are not for engines of any particular make, but are for an average type suitable for manufacturing purposes. Prices for the smaller sizes will be found to vary considerably.

ENGINES USING KEROSENE OIL.

Capital Costs.

B. H. P. Unit.	1¼	5	10	30	50
Cost of Engine complete with starting Gear .... (1)	$240.00	$380.00	$560.00	$1,400.00	$2,200.00
Cost of Installation and Accessories (2)	30.00	60.00	85.00	150.00	400.00
(1+2) Total Cost of Engine .... (3)	$270.00	$440.00	$645.00	$1,550.00	$2,600.00
Engine Foundations............. (4)	$15.00	$ 23.00	$ 33.00	$ 90.00	$160.00
Land and Building .... (5)	50.00	100.00	150.00	275.00	350.00
(4+5) Total Cap. Cost of Buildings (6)	$65.00	$123.00	$183.00	$365.00	$510.00
(3+6) Grand Total Cap. Costs .. (7)	$335.00	$563.00	$828.00	$1,915.00	$3,110.00
Cap. Costs per B.H.P.	$268.00	$112.60	$82.80	$63.83	$62.20

Fixed Charges.

B. H. P. Unit.	1¼	5	10	30	50
Interest on Capital, 5%	$16.75	$28.15	$41.40	$95.75	$155.50
Depreciation on Machinery, 6%	16.20	26.40	38.70	93.00	156.00
Depreciation on Building, 2%	1.30	2.46	3.66	7.30	10.20
Fire Ins. 1%, Taxes 1½%, Total 2½% .	8.38	14.08	20.70	47.88	77.75
Repair Building, 2%	1.30	2.46	3.66	7.30	10.20
Total	$43.93	$73.55	$108.12	$251.23	$409.65

Working Expenses.

Maintenance and Repairs..	3,000 hrs., 2%	$ 5.40	$ 8.80	$12.90	$31.00	$ 52.00
	6,600 hrs., 4%	10.80	17.60	25.80	62.00	104.00
Attendance	3,000 hrs.	30.00	60.00	90.00	120.00	140.00
	6,600 hrs.	60.00	120.00	180.00	240.00	280.00

Cost of Kerosene Oil per B.H.P. Hour, at 16 Cents per Gallon Delivered.

Average Load on Engine in % of Rated Capacity	100%	1.25 pts. 2.5 c.	1.17 pts. 2.34 c.	1.12 pts. 2.24 c.	1 pint 2.0 c.	1 pint 2.0 c.
	75%	1.4 pts. 2.8 c.	1.33 pts. 2.66 c.	1.27 pts. 2.54 c.	1.12 pts. 2.24 c.	1.12 pts. 2.24 c.
	50%	1.75 pts. 3.5 c.	1.55 pts. 3.10 c.	1.51 pts. 3.02 c.	1.40 pts. 2.80 c.	1.40 pts. 2.80 c.

Cost of Lubricating Oil, Waste and Sundries.

Average Load on Engine in % of Rated Capacity	100%	.06 c.	.05 c.	.04 c.	.04 c.	.03 c.
	75%	.08	.06	.04	.04	.03
	50%	.09	.07	.05	.05	.04

ENGINES USING KEROSENE OIL—Continued.

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, 3,000 HOURS YEARLY.

B. H. P. PER UNIT.	1¼	5	10	30	50
Fixed Charges	$43.93	$ 73.55	$108.12	$251.23	$409.65
Maintenance and Repairs	5.40	8.80	12.90	31.00	52.00
Attendance	30.00	60.00	90.00	120.00	140.00
Kerosene	93.75	351.00	672.00	1,800.00	3,000.00
Lubricating Oil and Sundries	2.25	7.50	12.00	36.00	45.00
TOTAL	$175.33	$500.85	$895.02	$2,238.23	$3,646.65
Cost per Year per B.H.P. of Average Demand	$140.26	$100.17	$89.50	$74.61	$72.93
Cost per B.H.P. Hour	4.68 c.	3.34 c.	2.98 c.	2.49 c.	2.43 c.
Cost per Year per B.H.P. of Rated Capacity	$140.26	$100.17	$89.50	$74.61	$72.93

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, 6,600 HOURS YEARLY.

Fixed Charges	$ 43.93	$ 73.55	$108.12	$251.23	$409.65
Maintenance and Repairs	10.80	17.60	25.80	62.00	104.00
Attendance	60.00	120.00	180.00	240.00	280.00
Kerosene	206.15	772.20	1,478.40	3,960.00	6,600.00
Lubricating Oil and Sundries	4.95	16.50	26.40	79.20	99.00
TOTAL	$325.83	$999.85	$1,818.72	$4,592.43	$7,492.65
Cost per Year per B.H.P. of Average Demand	$260.66	$199.97	$181.87	$153.08	$149.85
Cost per B.H.P. Hour	3.95 c.	3.03 c.	2.76 c.	2.31 c.	2.27 c.
Cost per Year per B.H.P. of Rated Capacity	$260.66	$199.97	$181.87	$183.08	$149.85

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 3,000 HOURS PER YEAR.

B. H. P. PER UNIT.	1¼	5	10	30	50
Fixed Charges	$43.93	$ 73.55	$108.12	$251.23	$409.65
Maintenance and Repairs	5.40	8.80	12.90	31.00	52.00
Attendance	30.00	60.00	90.00	120.00	140.00
Kerosene	78.75	299.25	571.50	1,512.00	2,520.00
Lubricating Oil and Sundries	2.25	6.75	9.00	27.00	33.75
TOTAL	$160.33	$448.35	$791.52	$1,941.23	$3,155.40
Cost per Year per B.H.P. of Average Demand	$171.02	$119.56	$105.54	$86.28	$84.14
Cost per B.H.P. Hour	5.70 c.	3.99 c.	3.52 c.	2.88 c.	2.80 c.
Cost per Year per B.H.P. of Rated Capacity	$145.27	$89.67	$79.15	$64.71	$63.11

ENGINES USING KEROSENE OIL—Continued.

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 6,600 HOURS PER YEAR.

Fixed Charges	$ 43.93	$ 73.55	$108.12	$251.23	$409.65
Maintenance and Repairs	10.80	17.60	25.80	62.00	104.00
Attendance	60.00	120.00	180.00	240.00	280.00
Kerosene	173.25	658.35	1,257.30	3,326.40	5,544.00
Lubricating Oil and Sundries	4.95	14.85	19.80	59.40	74.25
TOTAL	$292.93	$884.35	$1,591.02	$3,939.03	$6,411.90
Cost per Year per B.H.P. of Average Demand	$312.46	$235.83	$212.14	$175.07	$170.98
Cost per B.H.P. Hour	4.73 c.	3.57 c.	3.21 c.	2.65 c.	2.59 c.
Cost per Year per B.H.P. of Rated Capacity	$234.35	$176.87	$159.10	$131.30	$128.24

YEARLY COSTS, ENGINE RUNNING 50% RATED CAPACITY, 3,000 HOURS PER YEAR.

B. H. P. PER UNIT.	1½	5	10	30	50
Fixed Charges	$43.93	$ 73.55	$108.12	$251.23	$409.65
Maintenance and Repairs	5.40	8.80	12.90	31.00	52.00
Attendance	30.00	60.00	90.00	120.00	140.00
Kerosene	65.63	232.50	453.00	$1,260.00	$2,100.00
Lubricating Oil and Sundries	1.69	5.25	7.50	22.50	30.00
TOTAL	$146.65	$380.10	$671.52	$1,684.73	$2,731.65
Cost per Year per B.H.P. of Average Demand	$234.64	$152.04	$134.30	$112.32	$109.27
Cost per B.H.P. Hour	7.82 c.	5.07 c.	4.48 c.	3.74 c.	3.64 c.
Cost per Year per B.H.P. of Rated Capacity	$117.39	$76.02	$67.15	$56.16	$54.64

YEARLY COSTS, ENGINE RUNNING 50% RATED CAPACITY, 6,600 HOURS PER YEAR.

Fixed Charges	$ 43.93	$ 73.55	$108.12	$251.23	$409.65
Maintenance and Repairs	10.80	17.60	25.80	62.00	104.00
Attendance	60.00	120.00	180.00	240.00	280.00
Kerosene	144.39	511.50	996.60	2,772.00	4,620.00
Lubricating Oil and Sundries	3.72	11.55	16.50	49.50	66.00
TOTAL	$262.84	$734.20	$1,327.02	$3,374.73	$5,479.65
Cost per Year per B.H.P. of Average Demand	$420.54	$293.68	$265.40	$224.98	$219.19
Cost per B.H.P. Hour	6.37 c.	4.45 c.	4.02 c.	3.41 c.	3.32 c.
Cost per Year per B.H.P. of Rated Capacity	$210.27	$146.84	$132.70	$112.49	$109.59

APPROXIMATE CORRECTION TO BE APPLIED TO THE COST FOR B.H.P. YEAR AS SHOWN IN THE ESTIMATES FOR OIL ENGINES FOR EVERY 1 CENT VARIATION IN THE PRICE OF KEROSENE OIL PER GALLON.

NOTE 1.—To obtain the cost per B.H.P. hour due to a changed price of oil, correct the yearly cost per average B.H.P. as necessary and divide by the number of working hours in the years.

NOTE 2.—To obtain the yearly cost per B.H.P. of rated capacity due to changed price of oil, correct the yearly cost per average B.H.P. as necessary and multiply by the load factor the plant is working on.

SIZE OF UNIT.	LOAD FACTOR.	YEAR OF 3,000 HOURS.	YEAR OF 6,600 HOURS.
1½ B. H. P.	100%	$4.69	$10.32
	75%	5.25	11.55
	50%	6.56	14.43
5 B. H. P.	100%	4.39	9.66
	75%	5.00	11.00
	50%	5.81	12.78
10 B. H. P.	100%	4.20	9.24
	75%	4.76	10.47
	50%	5.66	12.45
30 B. H. P.	100%	3.75	8.25
	75%	4.20	9.24
	50%	5.25	11.55
50 B. H. P.	100%	3.75	8.25
	75%	4.20	9.24
	50%	5.25	11.55

ESTIMATE SHOWING COSTS OF INSTALLING AND WORKING GAS ENGINES USING ILLUMINATING GAS.

NOTE 1. These estimates are not for plant of any particular make, but represent the average cost of plant suitable for manufacturing purposes. No spare plant has been allowed. Prices for the smaller sized units will be found to vary considerably.

2. Working costs have been based on the assumption of fairly steady loads and intelligent supervision. If the load fluctuates, fuel consumption and costs will increase, even though the average load remains the same. Unless skilled attendance is provided working costs will be considerably increased.

3. The gas assumed for the purpose of estimate is gas similar to Toronto gas.

GAS ENGINES (ILLUMINATING GAS).

Capital Costs.

B.H.P. of Unit	1¼	5	10	30	50	100
Cost Complete (1)	$150.00	$250.00	$400.00	$1,000.00	$1,700.00	$3,300.00
Installation and Accessories (2)	25.00	50.00	75.00	125.00	200.00	350.00
(1+2) Cap. Cost Mach. (3)	$175.00	$300.00	$475.00	$1,125.00	$1,900.00	$3,650.00
Engine Foundations (4)	$17.50	$ 23.00	$ 33.00	$ 90.00	$160.00	$300.00
Land and Building (5)	50.00	100.00	150.00	275.00	350.00	500.00
(4+5) Total Cap. Cost Buildings (6)	$67.50	$123.00	$183.00	$365.00	$510.00	$800.00
(3+6) Grand Total Cap. Cost (7)	$242.50	$423.00	$658.00	$1,490.00	$2,410.00	$4,450.00
Cap. Cost per B.H.P.	$194.00	$84.60	$65.80	$49.67	$48.20	$44.50

Fixed Charges.

B.H.P. of Unit	1¼	5	10	30	50	100
Int. on Capital Costs, 5%	$12.13	$21.15	$32.90	$74.50	$120.50	$222.50
Dep. on Machinery, 6%	10.50	18.00	28.50	67.50	114.00	219.00
Dep. on Building, 2%	1.35	2.46	3.66	7.30	10.20	16.00
Fire Ins. 1%, Taxes 1½%; Total 2½%	6.06	10.55	16.45	37.25	60.25	111.25
Repairs on Building, 2%	1.00	2.00	3.00	5.50	7.00	10.00
Total Fixed Charges	$31.04	$54.16	$84.51	$192.05	$311.95	$578.75

WORKING EXPENSES.

Maintenance and Repairs of Machinery.

Year of 3,000 Hours, 2%	$ 3.50	$ 6.00	$ 9.50	$22.50	$38.00	$ 73.00
Year of 6,600 Hours, 4%	7.00	12.00	19.00	45.00	76.00	146.00

Attendance.

Year of 3,000 Hours	$30.00	$ 60.00	$ 90.00	$120.00	$140.00	$200.00
Year of 6,600 Hours	60.00	120.00	180.00	240.00	280.00	400.00

Cubic Feet of Gas per B.H.P Hour, at 75 Cents per 1,000 C. F.

(Gas 600 B.T.U. per C.F.)

Ave. load on Engine in % of rated capacity						
100%	26 c.f. 1.95 c.	24 c.f. 1.80 c.	23 c.f. 1.73 c.	21 c.f. 1.58 c.	19 c.f. 1.43 c.	18 c.f. 1.35 c.
75%	29 c.f. 2.18 c.	27 c.f. 2.03 c.	25 c.f. 1.88 c.	23 c.f. 1.73 c.	21 c.f. 1.58 c.	20 c.f. 1.50 c.
50%	38 c.f. 2.85 c.	35 c.f. 2.63 c.	30 c.f. 2.25 c.	27 c.f. 2.03 c.	25 c.f. 1.88 c.	23 c.f. 1.73 c.

Cost of Lubricating Oil, Waste and Sundries, per B.H.P. Hour.

Ave. load on Engine in % of rated capacity						
100%	.06 c.	.05 c.	.04 c.	.04 c.	.03 c.	.03 c.
75%	.08 c.	.06 c.	.04 c.	.04 c.	.03 c.	.03 c.
50%	.09 c.	.07 c.	.05 c.	.05 c.	.04 c.	.04 c.

GAS ENGINES (ILLUMINATING GAS)—Continued.

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, 3,000 HOURS PER YEAR.

B.H.P. of Unit	1¼	5	10	30	50	100
Fixed Charges	$ 31.04	$ 54.16	$ 84.51	$192.05	$311.95	$578.75
Maintenance and Repairs on Machinery	3.50	6.00	9.50	22.50	38.00	73.00
Attendance	30.00	60.00	90.00	120.00	140.00	200.00
Gas	73.13	270.00	519.00	1,422.00	2,145.00	4,050.00
Oil and Sundries	2.25	7.50	12.00	36.00	45.00	90.00
Total	$139.92	$397.66	$715.01	$1,792.55	$2,679.95	$4,991.75
Cost per Year per B.H.P. of Average Demand	$111.94	$79.53	$71.50	$59.75	$53.60	$49.92
Cost per B.H.P. Hour	3.73 c.	2.65 c.	2.38 c.	1.99 c.	1.79 c.	1.66 c.
Cost per Year per B.H.P. of Rated Capacity	$111.94	$79.53	$71.50	$59.75	$53.60	$49.92

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, 6,600 HOURS PER YEAR.

Fixed Charges	$ 31.04	$ 54.16	$ 84.51	$192.05	$311.95	$578.75
Maintenance and Repairs on Machinery	7.00	12.00	19.00	45.00	76.00	146.00
Attendance	60.00	120.00	180.00	240.00	280.00	400.00
Gas	160.89	594.00	1,141.80	3,128.40	4,719.00	8,910.00
Oil and Sundries	4.95	16.50	26.40	79.20	99.00	198.00
Total	$263.88	$796.66	$1,451.71	$3,684.63	$5,485.95	$10,232.75
Cost per Year per B.H.P. of Average Demand	$211.10	$159.33	$145.17	$122.82	$109.72	$102.33
Cost per B.H.P. Hour	3.20 c.	2.41 c.	2.20 c.	1.86 c.	1.66 c.	1.55 c.
Cost per Year per B.H.P. of Rated Capacity	$211.10	$159.33	$145.17	$122.82	$109.72	$102.33

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 3,000 HOURS PER YEAR.

B.H.P. of Unit	1¼	5	10	30	50	100
Fixed Charges	$ 31.04	$ 54.16	$ 84.51	$192.05	$311.95	$578.75
Maintenance and Repairs on Machinery	3.50	6.00	9.50	22.50	38.00	73.00
Attendance	30.00	60.00	90.00	120.00	140.00	200.00
Gas	61.31	228.38	423.00	1,167.75	1,777.50	3,375.00
Oil and Sundries	2.25	6.75	9.00	27.00	33.75	67.50
Total	$128.10	$355.29	$616.01	$1,529.30	$2,301.20	$4,294.25
Cost per Year per B.H.P. of Average Demand	$136.58	$94.74	$82.15	$67.97	$61.36	$57.25
Cost per B.H.P. Hour	4.55 c.	3.16 c.	2.74 c.	2.26 c.	2.04 c.	1.91 c.
Cost per Year per B.H.P. of Rated Capacity	$102.44	$71.06	$61.60	$50.98	$46.02	$42.94

GAS ENGINES (ILLUMINATING GAS)—Continued.

Yearly Costs, Engine Running 75% Rated Capacity, 6,600 Hours per Year.

Fixed Charges	$ 31.04	$ 54.16	$ 84.51	$192.05	$311.95	$578.75
Maintenance and Repairs of Machinery	7.00	12.00	19.00	45.00	76.00	146.00
Attendance	60.00	120.00	180.00	240.00	280.00	400.00
Gas	134.88	502.43	930.60	2,569.05	3,910.50	7,425.00
Oil and Sundries	4.95	14.85	19.80	59.40	74.25	148.50
Total	$237.87	$703.44	$1,233.91	$3,105.50	$4,652.70	$8,698.25
Cost per Year per B.H.P. of Average Demand	$253.73	$187.58	$164.52	$138.02	$124.07	$115.98
Cost per B.H.P. Hour	3.84 c.	2.84 c.	2.49 c.	2.09 c.	1.88 c.	1.76 c.
Cost per Year per B.H.P. of Rated Capacity	$190.30	$140.67	$123.39	$103.52	$93.05	$86.98

Yearly Costs, Engine Running 50% Rated Capacity, 3,000 Hours per Year.

B.H.P. of Unit	1½	5	10	30	50	100
Fixed Charges	$ 31.04	$ 54.16	$ 84.51	$192.05	$311.95	$578.75
Maintenance and Repairs of Machinery	3.50	6.00	9.50	22.50	38.00	73.00
Attendance	30.00	60.00	90.00	120.00	140.00	200.00
Gas	53.44	197.25	337.50	913.50	1,410.00	2,595.00
Oil, Waste and Sundries	1.69	5.25	7.50	22.50	30.00	60.00
Total	$119.67	$322.66	$529.01	$1,270.55	$1,929.95	$3,506.75
Cost per Year per B.H.P. of Average Demand	$191.47	$129.06	$105.80	$84.70	$77.20	$70.14
Costs per B.H.P. Hour	6.38 c.	4.30 c.	3.53 c.	2.82 c.	2.57 c.	2.34 c.
Cost per Year per B.H.P. of Rated Capacity	$95.74	$64.53	$52.90	$42.35	$38.60	$35.07

Yearly Costs, Engine Running 50% Rated Capacity, 6,600 Hours per Year.

Fixed Charges	$ 31.04	$ 54.16	$ 84.51	$192.05	$311.95	$578.75
Maintenance and Repairs of Machinery	7.00	12.00	19.00	45.00	76.00	146.00
Attendance	60.00	120.00	180.00	240.00	280.00	400.00
Gas	117.56	433.95	742.50	2,009.70	3,102.00	5,709.00
Oil, Waste, etc.	3.71	11.55	16.50	49.50	66.00	132.00
Total	$219.31	$631.66	$1,042.51	$2,536.25	$3,835.95	$6,965.75
Cost per Year per B.H.P. of Average Demand	$350.90	$252.66	$208.50	$169.08	$153.44	$139.32
Cost per B.H.P. Hour	5.32 c.	3.83 c.	3.16 c.	2.56 c.	2.32 c.	2.11 c.
Cost per Year per B.H.P. of Rated Capacity	$175.46	$126.33	$104.25	$84.54	$76.72	$69.66

GAS ENGINES (ILLUMINATING GAS)—Continued.

APPROXIMATE ALTERATION IN THE YEARLY COST PER AVERAGE B.H.P. DUE TO A CHANGE IN PRICE OF GAS OF 5 CENTS PER 1,000 C.F.

NOTE 1.—To obtain cost per B.H.P. hour due to a change in the price of gas, correct the yearly average cost as necessary and divide by the number of working hours in the year.

NOTE 2.—To obtain the yearly cost per B.H.P. of rated capacity due to a change in price, correct the yearly average cost as necessary, and multiply by the load factor that the plant is working on.

B.H.P. of Unit.	Load Factor.	Year of 3,000 Hours.	Year of 6,600 Hours.
1¼	100%	$3.90	$8.58
	75%	4.36	9.59
	50%	5.70	12.54
5	100%	3.60	7.92
	75%	4.05	8.91
	50%	5.25	11.55
10	100%	3.45	7.59
	75%	3.75	8.25
	50%	4.50	9.90
30	100%	3.16	6.95
	75%	3.45	7.59
	50%	4.05	8.91
50	100%	2.86	6.29
	75%	3.16	6.95
	50%	3.74	8.23
100	100%	2.70	5.94
	75%	3.00	6.60
	50%	3.45	7.59

ESTIMATES SHOWING THE COSTS OF INSTALLING AND WORKING ENGINES USING NATURAL GAS.

NOTE 1. The estimates are not for engines of any particular make, but represent an average cost for engines suitable for manufacturing purposes. No spare plant has been allowed. There is a considerable variation in the price of the smaller sized engines.

2. Working costs are based on the assumption of fairly steady loads and intelligent supervision. If the load fluctuate, fuel consumption and costs will increase, even though the average load remain the same.

3. For the purpose of estimate, natural gas of the heat value and price of gas now being sold in Hamilton and Western Ontario has been assumed.

GAS ENGINES (NATURAL GAS).

Capital Charges.

B.H.P. of Unit	1¼	5	10	30	50	100	300	500
Cost of Engine Complete (1)	$200.00	$250.00	$400.00	$1,000.00	$1,700.00	$3,300.00	$9,600.00	$16,000.00
Installation and Accessories (2)	25.00	50.00	75.00	125.00	200.00	350.00	1,000.00	1,500.00
(1+2) Total Capital Costs Machinery (3)	$225.00	$300.00	$475.00	$1,125.00	$1,900.00	$3,650.00	$10,600.00	$17,500.00
Engine Foundations (4)	$15.00	$ 23.00	$ 33.00	$ 90.00	$160.00	$300.00	$ 800.00	$1,300.00
Land and Buildings (5)	50.00	100.00	150.00	275.00	350.00	500.00	1,200.00	1,700.00
(4+5) Total Cost Land and Buildings (6)	$65.00	$123.00	$183.00	$365.00	$510.00	$800.00	$2,000.00	$3,000.00
(3+6) Total Capital Cost (7)	$290.00	$423.00	$658.00	$1,490.00	$2,410.00	$4,450.00	$12,600.00	$20,500.00
Capital Cost per B.H.P.	$231.90	$84.60	$65.80	$49.67	$48.20	$44.50	$42.00	$41.00

Fixed Charges.

B.H.P. of Unit	1¼	5	10	30	50	100	300	500
Interest on Capital Cost, 5%	$14.50	$21.15	$32.90	$74.50	$120.50	$222.50	$630.00	$1,025.00
Depreciation on Machinery, 6%	13.50	18.00	28.50	67.50	114.00	219.00	636.00	1,050.00
Depreciation on Building, 2%	1.30	2.46	3.66	7.30	10.20	16.00	40.00	60.00
Taxes and Insurance, 2½%	7.25	10.58	16.45	37.25	60.25	111.25	315.00	512.50
Repair on Buildings, 2%	1.30	2.46	3.66	7.30	10.20	16.00	40.00	60.00
Total Fixed Charges	$37.85	$54.65	$85.17	$193.85	$315.15	$584.75	$1,661.00	$2,707.50

GAS ENGINES (NATURAL GAS)—Continued.

Working Expenses.

DEPRECIATION AND REPAIR ON MACHINERY.

Year of 3,000 Hours	$4.50	$6.00	$ 9.50	$22.50	$38.00	$ 73.00	$212.00	$350.00
Year of 6,600 Hours	9.00	12.00	19.00	45.00	76.00	146.00	424.00	700.00

ATTENDANCE.

Year of 3,000 Hours	$30.00	$ 60.00	$ 90.00	$120.00	$140.00	$200.00	$400.00	$ 600.00
Year of 6,600 Hours	60.00	120.00	180.00	240.00	280.00	400.00	800.00	1,200.00

COST OF GAS PER B.H.P. HOUR. QUALITY, 980 B.T.U. PER C.F.; PRICE, 20 CENTS PER 1,000 C.F.

Average Load, 100% Rated Capacity	16 c.f. .32 c.	15 c.f. .30 c.	14 c.f. .28 c.	13 c.f. .26 c.	12 c.f. .24 c.	11 c.f. .22 c.	11 c.f. .22 c.	11 c.f. .22 c.
Average Load, 75% Rated Capacity	18 c.f. .36 c.	17 c.f. .34 c.	16 c.f. .32 c.	14 c.f. .28 c.	13 c.f. .26 c.	12 c.f. .24 c.	12 c.f. .24 c.	12 c.f. .24 c.
Average Load, 50% Rated Capacity	20 c.f. .40 c.	20 c.f. .40 c.	18 c.f. .36 c.	17 c.f. .34 c.	16 c.f. .32 c.	14 c.f. .28 c.	14 c.f. .28 c.	14 c.f. .28 c.

COST OF LUBRICATING OIL, WASTE AND SUNDRIES, PER B.H.P. HOUR.

Average Load, 100% Rated Capacity	.06 c.	.05 c.	.04 c.	.04 c.	.03 c.	.03 c.	.02 c.	.02 c.
Average Load, 75% Rated Capacity	.08 c.	.06 c.	.04 c.	.04 c.	.03 c.	.03 c.	.02 c.	.02 c.
Average Load, 50% Rated Capacity	.09 c.	.07 c.	.05 c.	.05 c.	.04 c.	.04 c.	.03 c.	.03 c.

GAS ENGINES (NATURAL GAS)—Continued.

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, 3,000 HOURS PER YEAR.

B.H.P. of Unit	1½	5	10	30	50	100	300	500
Fixed Charges	$37.85	$54.65	$85.17	$193.85	$315.15	$584.75	$1,661.00	$2,707.50
Attendance	30.00	60.00	90.00	120.00	140.00	200.00	400.00	600.00
Maintenance and Repairs on Machinery	4.50	6.00	9.50	22.50	38.00	73.00	212.00	350.00
Gas	12.00	45.00	84.00	234.00	360.00	660.00	1,980.00	3,300.00
Oil, Waste and Sundries	2.25	7.50	12.00	36.00	45.00	90.00	180.00	300.00
TOTAL COST PER YEAR	$86.60	$173.15	$280.67	$606.35	$898.15	$1,607.75	$4,433.00	$7,257.50
Cost per Year per B.H.P. of Average Demand	$69.28	$34.63	$28.07	$20.21	$17.96	$16.08	$14.78	$14.52
Cost per B.H.P Hour	2.31 c.	1.15 c.	.94 c.	.67 c.	.60 c.	.54 c.	.49 c.	.48 c.
Cost per Year per B.H.P. of Rated Capacity	$69.28	$34.63	$28.07	$20.21	$17.96	$16.08	$14.78	$14.52

YEARLY COSTS, ENGINE RUNNING 100% RATED CAPACITY, 6,600 HOURS PER YEAR.

Fixed Charges	$37.85	$ 54.65	$ 85.17	$193.85	$315.15	$584.75	$1,661.00	$2,707.50
Attendance	60.00	120.00	180.00	240.00	280.00	400.00	800.00	1,200.00
Maintenance and Repairs on Machinery	9.00	12.00	19.00	45.00	76.00	146.00	424.00	700.00
Gas	26.40	99.00	184.80	514.80	792.00	1,452.00	4,356.00	7,260.00
Oil, Waste and Sundries	4.95	16.50	26.40	79.20	99.00	198.00	396.00	660.00
TOTAL COST PER YEAR	$138.20	$302.15	$495.37	$1,072.85	$1,562.15	$2,780.75	$7,637.00	$12,52[illegible].50
Cost per Year per B.H.P. of Average Demand	$110.56	$60.43	$49.54	$35.76	$31.24	$27.81	$25.46	$25.06
Cost per B.H.P. Hour	1.68 c.	0.92 c.	0.75 c.	0.54 c.	0.47 c.	0.42 c.	0.39 c.	0.38 c.
Cost per Year per B.H.P. of Rated Capacity	$110.56	$60.43	$49.54	$35.76	$31.24	$27.81	$25.46	$25.06

GAS ENGINES (NATURAL GAS)—Continued

Working Expenses.

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 3,000 HOURS PER YEAR.

B.H.P. OF UNIT	1¼	5	10	30	50	100	300	500
Fixed Charges	$37.85	$54.65	$85.17	$193.85	$315.15	$584.75	$1,661.00	$2,707.50
Attendance	30.00	60.00	90.00	120.00	140.00	200.00	400.00	600.00
Maintenance and Repairs on Machinery	4.50	6.00	9.50	22.50	38.00	73.00	212.00	350.00
Gas	10.13	38.25	72.00	189.00	292.50	540.00	1,620.00	2,700.00
Oil, Waste and Sundries	2.25	6.75	9.00	27.00	33.75	67.50	135.00	225.00
TOTAL COST PER YEAR	$84.73	$165.65	$265.67	$552.35	$819.40	$1,465.25	$4,028.00	$6,582.50
Cost per Year per B.H.P. of Average Demand	$90.38	$44.17	$35.42	$24.55	$21.85	$19.54	$17.90	$17.55
Cost per B.H.P. Hour	3.01 c.	1.47 c.	1.18 c.	.82 c.	.73 c.	.65 c.	.60 c.	.59 c.
Cost per Year per B.H.P. of Rated Capacity	$67.78	$33.13	$26.57	$18.41	$16.39	$14.65	$13.43	$13.17

YEARLY COSTS, ENGINE RUNNING 75% RATED CAPACITY, 6,600 HOURS PER YEAR.

Fixed Charges	$37.85	$54.65	$ 85.17	$193.85	$315.15	$584.75	$1,661.00	$2,707.50
Attendance	60.00	120.00	180.00	240.00	280.00	400.00	800.00	1,200.00
Maintenance and Repairs on Machinery	9.00	12.00	19.00	45.00	76.00	146.00	424.00	700.00
Gas	22.29	84.15	158.40	415.80	643.50	1,188.00	3,564.00	5,940.00
Oil, Waste and Sundries	4.95	14.85	19.80	59.40	74.25	148.50	297.00	495.00
TOTAL COST PER YEAR	$134.09	$285.65	$462.37	$954.05	$1,388.90	$2,467.25	$6,746.00	$11,042.50
Cost per Year per B.H.P. of Average Demand	$143.03	$76.17	$61.65	$42.40	$37.04	$32.90	$29.98	$29.45
Cost per B.H.P. Hour	2.17 c.	1.15 c.	0.93 c.	0.64 c.	0.56 c.	0.50 c.	0.45 c.	0.45 c.
Cost per Year per B.H.P. of Rated Capacity	$107.27	$57.13	$46.23	$31.80	$27.78	$24.67	$22.49	$22.09

GAS ENGINES (NATURAL GAS)—Continued.

Working Expenses.

YEARLY COSTS, ENGINE RUNNING 50% RATED CAPACITY, 3,000 HOURS PER YEAR.

SIZE OF UNIT B.H.P.	1¼	5	10	30	50	100	300	500
Fixed Charges	$37.85	$54.65	$85.17	$193.85	$315.15	$584.75	$1,661.00	$2,707.50
Attendance (1 Shift)	30.00	60.00	90.00	120.00	140.00	200.00	400.00	600.00
Maintenance and Repairs on Machinery	4.50	6.00	9.50	22.50	38.00	73.00	212.00	350.00
Gas	7.50	30.00	54.00	153.00	240.00	420.00	1,260.00	2,100.00
Oil, Waste and Sundries	1.69	5.25	7.50	22.50	30.00	60.00	135.00	225.00
TOTAL COST PER YEAR	$81.54	$155.90	$246.17	$511.85	$763.15	$1,337.75	$3,668.00	$5,982.50
Cost per Year per B.H.P. of Average Demand	$130.46	$62.36	$49.23	$34.12	$30.53	$26.76	$24.45	$23.93
Cost per B.H.P. Hour	4.35 c.	2.08 c.	1.64 c.	1.14 c.	1.02 c.	.89 c.	.82 c.	.80 c.
Cost per Year per B.H.P. of Rated Capacity	$65.23	$31.18	$24.62	$17.06	$15.26	$13.38	$12.23	$11.97

YEARLY COSTS, ENGINE RUNNING 50% RATED CAPACITY, 6,600 HOURS PER YEAR.

Fixed Charges	$37.85	$ 54.65	$ 85.17	$193.85	$315.15	$584.75	$1,661.00	$2,707.50
Attendance (2 Shifts)	60.00	120.00	180.00	240.00	280.00	400.00	800.00	1,200.00
Maintenance and Repairs on Machinery	9.00	12.00	19.00	45.00	76.00	146.00	424.00	700.00
Gas	16.50	66.00	118.80	336.60	528.00	924.00	2,772.00	4,620.00
Oil, Waste and Sundries	3.72	11.55	16.50	49.50	66.00	132.00	297.00	495.00
TOTAL COST PER YEAR	$127.07	$264.20	$419.47	$864.95	$1,265.15	$2,186.75	$5,954.00	$9,722.50
Cost per Year per B.H.P. of Average Demand	$203.31	$105.68	$83.90	$57.66	$50.61	$43.74	$39.69	$38.89
Cost per B.H.P. Hour	3.08 c.	1.60 c.	1.27 c.	0.87 c.	0.77 c.	0.66 c.	0.60 c.	0.59 c.
Cost per Year per B.H.P. of Rated Capacity	$101.66	$52.84	$41.95	$28.83	$25.30	$21.87	$19.85	$19.45

APPROXIMATE ALTERATION IN THE YEARLY COST PER AVERAGE B.H.P. DUE TO A CHANGE IN PRICE OF GAS OF 1 CENT PER 1,000 C. F.

NOTE 1.—To obtain the cost per B.H.P. hour due to change in price, correct the yearly average cost as necessary, and decide by the number of working hours in the year.

NOTE 2.—To obtain the yearly cost per B.H.P. of rated capacity due to change in price, correct the yearly average cost as necessary, and multiply by the load factor that the plant is working on.

B.H.P. of Unit.	Rated Capacity.	Year of 3,000 Hours.	Year of 6,600 Hours.
1½	100%	$0.48	$1.06
	75%	.54	1.19
	50%	.60	1.32
5	100%	.45	.99
	75%	.51	1.12
	50%	.60	1.32
10	100%	.42	.92
	75%	.48	1.06
	50%	.54	1.19
30	100%	.39	.86
	75%	.42	.92
	50%	.51	1.12
50	100%	.36	.79
	75%	.39	.86
	50%	.48	1.06
100	100%	.33	.73
	75%	.36	.79
	75%	.42	.92
300	100%	.33	.73
	75%	.36	.79
	50%	.42	.92
500	100%	.33	.73
	75%	.36	.79
	50%	.42	.92

PART V.

1. *General Conclusions Regarding the Power Situation in Ontario.*

PART V.

GENERAL CONCLUSIONS REGARDING THE POWER SITUATION IN ONTARIO.

Fuel supply.

The crucial point in any general discussion of the conditions governing the economic generation of power in Ontario will always be the cost of fuel supply.

Petroleum and natural gas.

Excluding hydraulic power, coal is the only fuel likely to permanently enable the power demands of a large manufacturing community to be satisfactorily met. Petroleum is not found in sufficiently large quantities to meet the demands of both light and power users, and in the competition for its use the light user, being able to pay more for it, will ultimately fix the price above that which the power user can economically pay.

Where the local demand for natural gas for lighting and domestic purposes is insufficient to utilize the whole product of the wells, it may become of considerable value to the manufacturer for power purposes as natural gas cannot be stored and transported like petroleum.

Unfortunately there is no certainty that the supply of natural gas in any locality will be permanent, or even sufficiently long continued to make it advisable to put in a large plant which is solely dependent upon natural gas as its source of power, although, when close to the wells, this is probably the cheapest source of power that can be obtained. Plants using natural gas as a fuel under boilers and in gas engines are to-day in operation, but are so arranged that they can be worked with coal or producer gas whenever the wells show signs of becoming exhausted, and in considering natural gas as a source of power, this contingency should not be overlooked.

Wood for fuel.

Wood is becoming too expensive to be used to any appreciable extent as a fuel, more especially in the more settled portions of the province where power is most largely required.

Absence of local sources of coal supply.

Up to the present, the absence of local sources of coal supply in the province has rendered the power user dependent on the coal fields of the United States for his fuel. The increased and increasing demand there for coal has reached a point where the question of the exhaustion of the present sources of supply of the better grades of coal is already a matter of some concern, and in conjunction with

other factors, has enabled the coal owners to increase prices until to-day the price of coal used, in one specific case in Toronto, is about 45% higher than it was eleven years ago, and now stands at a price 9% above the average price of the past eleven years, even including in this average the high prices obtained a few years ago during the coal famine.

No grounds can be seen for anticipating that this increase in the price of coal will not continue, and as the coal becomes dearer the producer gas plant will compete more and more successfully with the steam-driven plant, even in those industries that require steam for heating. Were it not for the existence of large water powers in the province it might be confidently predicted that in the future the producer gas plant, as it developed and its reliability increased, would be as common in Ontario as the steam plant is to-day and the steam plant as rare as the gas plant.

Water power.

The water powers of the province, if properly conserved, are sufficient to supply the local power demands beyond any period in the future that can be intelligently anticipated at present, and are so distributed as to enable practically the whole province to obtain by electrical distribution the advantages of hydro-electric power without having to pay an excessive charge for its transmission. These water powers which are to-day valuable will become much more valuable as the price of coal increases, and if controlled and developed so that hydro-electric power is sold at a price based on the cost of development and transmission, and not at a price based on the cost of power generated by the next dearer means available, they will go far towards mitigating the effects of an increasing price of coal. Assuming that they will be so controlled, the conditions which make it possible for the producer gas plant to displace the steam driven plant will also operate at least as strongly towards the displacement of the producer gas plant by hydro-electric power. An increase in the price of coal will make it relatively cheaper to produce power by means of a producer gas plant than by means of a steam plant, but it will make the power produced by either a steam or gas plant more expensive than it is now and consequently will increase the areas within which hydro-electric power will give a cheaper power service than power produced from coal used either in steam or producer gas plants.

Hydro-electric power.

As hydro-electric power can only be economically transmitted over large areas when considerable blocks of power are dealt with, it may be expected that the producer gas plant will in many cases occupy a transitory position between steam and hydro-electric power, while the power demands of an area are reaching a size that will make

the transmission of the nearest hydro-electric power economically possible. In making any comparisons between the cost of hydro-electric power and power locally generated, the cost of a B.H.P. shown in these estimates should be increased about 15% in order to obtain the equivalent cost to the power user of an E.H.P. The figure thus obtained, as it includes an allowance for interest on capital and depreciation, will only hold good for comparisons in the case of new power installations. In making comparisons with a view to arriving at the figure at which hydro-electric power will be able to compete with power from installations already in existence it is necessary to consider that fixed charges on account of capital have already been incurred and must be provided for, and the deciding point will be whether the cost of hydro-electric power will be less than present operating expenses. If it is not then the power consumer will probably wait until large alterations or a new plant are necessary before he will use hydro-electric power. Furthermore, the figures in the estimates submitted for a basis of comparison are only average figures, and where the cost of transmitting hydro-electric power makes it equivalent to the cost of power as shown, it will not displace all the power used in the area considered, but only in cases where the cost of the locally generated power is above the average. In such cases probably two-thirds to three-fourths of the total power developed in any area will be costing more than the figures given in the estimates, as the power plants will include a number which are obsolete or working under unfavorable conditions, whereas the estimates are for up-to-date plants working under favorable conditions. When hydro-electric power can be sold at a price, say 10% below the operating expenses for locally generated power as calculated in this report, it may be expected that the hydro-electric power will displace practically all other power.

For installations using steam for heating or other purposes, hydro-electric power must be sold at a cost of 10% to 25% below the cost of steam power as shown in the tables according as the exhaust steam is used part of the year for heating or the whole year for manufacturing purposes. The exact calculation would be to add 15% to the cost of a B.H.P. as shown in the estimates and deduct the cost that would be incurred in providing steam from a separate source for heating or manufacturing purposes.

When it appears that the cost of power from any one source as compared with another will be approximately the same, the case must be dealt with on its merits as a specific proposition, outside the scope of this report, which is, and only can be, applicable to the general average cost of power production in the province.

Summary of conclusions.

The main results of this study of the conditions affecting or likely to affect the cost of generating power in Ontario may be shortly summarized as follows:—

1. Users of small amounts of power will be best served by electric power where it can be obtained at a price per E.H.P. not exceeding by more than 15% to 25% the cost per B.H.P. of power developed by gas, gasoline or oil engines. If electric power is not obtainable their wants will be most satisfactorily met by means of a small gas, gasoline or oil engine.

2. Users of large amounts of power where the load fluctuates will be justified in paying for electric power 30% more than the cost per B.H.P. if obtained from one of the prime movers shown in the estimates. If they cannot get electric power, steam power will give them the most satisfactory service.

3. Power users who require steam for heating purposes will only be justified in paying for electric power per E.H.P. a price equivalent to 80% to 85% of the cost of steam power per B.H.P., as shown in these estimates. If it cannot be obtained for this they will be best served by a steam engine.

4. Where the cost of producer gas power per B.H.P. does not work out 15% below the cost of hydro-electric power per E.H.P., it will be advisable to use hydro-electric power. Producer gas plants at present are only advisable for those power users having a fairly steady load and who require fairly large quantities of power, or who use gas for other purposes, such as annealing, brazing, or who may anticipate trouble from smoke nuisance by-laws. In the future the increasing price of coal in Ontario will probably allow producer gas plants to successfully compete with steam plants, even in those cases where the exhaust steam could have been used for heating and manufacturing purposes. This increase in the price of coal will also, however, extend the areas over which hydro-electric power can be profitably distributed, and the producer gas plant will probably only occupy an intermediary position in the displacement of steam by hydro-electric power.

5. Natural gas in some parts of the province, may, for a time, enable power to be produced cheaper than from any other source. The lack of permanence of the natural gas supply will not, however, justify a power user in sinking any considerable capital in a power plant to use natural gas unless when the supply is exhausted he can continue to produce power with producer gas cheaper than by any other means.

6. The value of the water powers of the province to the province as a whole depends on their conservation and development along lines which will require the selling price of hydro-electric power to be based on the cost of its development and transmission and not on the cost of generating power by some other agency to compete with it.

APPENDIX I.

REPORT OF MR. STOCKING.

Toronto, Feb. 3rd, 1908.

P. W. SOTHMAN, Esq.,
Chief Engineer of Hydro-Electric Power Commission,

DEAR SIR:—

I submit herewith a report on gas producer plants, as I found them in ————. Included in this report are estimates of costs of power for the different plants visited. In many cases the information obtained was not sufficient to make a complete estimate of costs, but where such information was lacking, values were taken which would be the most favorable to the cheap working of the plant. There is no doubt in my mind that the real costs per H.P. hour would exceed in almost every case the results obtained in these estimates.

In this report letters have been substituted for the firms' names, as follows:—

(*A*) Messrs.————. Plant abandoned.
(*B*) Messrs.———— Plant abandoned.
(*C*) Messrs.————. Plant abandoned.
(*D*) Messrs.————. Plant abandoned.
(*E*) Messrs.————.
(*F*) Messrs.————.
(*G*) Messrs.————. Interested in gas plants.
(*H*) Messrs.————. Interested in gas plants.

The two latter firms deal in gas engines and their figures are interesting on this account. (*G*) Messrs. ———— (gas plant) is especially interesting, as the plant was exhibited as being a very cheap and reliable source of power. (See Table on page 38*a*.)

Yours very truly,
(Sgd.) F. T. STOCKING,
Asst. Engineer.

GAS PRODUCER PLANTS.

In securing information regarding gas producer plants, one thing is very noticeable, viz., that the maximum load developed is almost invariably taken as the average running load, and in many cases, the idea of the owners as to the maximum load really carried is very vague. They usually consider that the engine is developing very nearly its full rated power, and take this as the average load on the engine. Such a load, of course, excepting in very special cases, is impossible to obtain.

In the following lists of costs the information furnished by the owners was taken as being correct, excepting in a few instances where their estimate of the load carried could be plainly shown as being incorrect. In such cases, the information obtained was checked over carefully and the greatest possible value for the load, consistent with the facts, was taken.

As a consequence, the costs per H.P. given are misleading in nearly every example, as the high load factor taken renders the majority of these costs too low.

A marked lack of careful accounting prevails with the greater number of companies. Coal and attendance costs are usually kept, but, as these two items combined are usually less than one-half the total cost, a proper conception of this total cost cannot be obtained from them.

(*C*) was the only place visited where a careful account was kept of all items. The only item in the account which was not given was the actual cost of gas plant installed. The figures of the company included the cost of generators. A very liberal amount, however, was deducted for these generators with results as shown. Information from other companies, while accurate in the main, was lacking in a number of items, which would go to make up the costs, and this, no doubt, has led to the impression by some users that gas plants are an exceptionally cheap source of power. All the plants visited have had instances of failure of power due to ignition, or other causes, and it is almost universally admitted that producer engines are not wholly reliable.

* * * * * * *

(Table of statistics included in Table on page 38*a*.)

Performance of Individual Plants.

(*A*) Installed in 1907 under certain guarantees of working, which it failed to perform. Great trouble was experienced in generating

the gas. Pea anthracite coal was purchased from a number of different dealers, hoping to find a quality of coal suitable for the producer, but all to no purpose. The producer was of English make and it was thought that its failure to work properly was due to poor quality of American coal. No coal, however carefully selected, was found which would produce gas in sufficient quantities. After three months' careful effort and considerable expense, this plant was abandoned. It is very uncertain what load was carried by this plant. The figures were given by the owner, but it is probable that the average load was much below that given.

(*B*) Plant installed in 1905 and run for two years. Yearly costs, exclusive of capital costs, for this plant were kept with a fair amount of care and the total operating costs were obtained. The only separate item, however, which could be secured was the cost of attendance. The total yearly cost as given is considered to be reasonably correct, which leaves the load factor as the only uncertain element in the estimate. The owner claimed that the engine was carrying full load. At times this was no doubt correct, but a factory load having an average load factor for the whole year of even 80 per cent. is something almost unheard of. However, to be fair, the high load factor has been taken. At the end of two years, the load became too heavy for the plant, which was consequently abandoned. The Owner claimed that there was insufficient space to install a larger plant, hence, electric power was substituted. If the plant had been a success, it is reasonable to suppose that an electric motor just large enough to carry the overload would have been used.

(*C*) As previously stated, an account was kept of all items of cost for this plant, and the information, therefore, is the most accurate of any in the list.

The plant was installed in 1906 and ran eleven months. During all this time it proved very unsatisfactory. Trouble was experienced in producing the proper gas in sufficient quantities. The plant consisted of two engines with a total capacity of 86 H.P., supplied by a producer of 100 rated H.P. One engine would run comparatively well, but when the second was started, the producer would frequently fail to develop sufficient gas. Great trouble was also experienced from overheating of engine bearings and stops occurred from this cause. The plant was placed in the basement with insufficient ventilation, and a number of cases of carbon monoxide poisoning resulted. The engines were direct connected to generators supplying electric power for wood-working machinery and for lighting the building. Considerable annoyance was experienced from the lights burning

dim when a heavier load came on the engine, causing them to slow down. After eleven months, during which time no expense was spared to make the plant a success, it was abandoned and electric power substituted.

(*D*) This plant was not put in the list, as its operation was so unsuccessful as to render it impossible to form an idea as to costs. This plant was erected in 1907 and experimented with about three months by the people installing same. According to the statement of the owner of the factory, this plant never operated, even under light load, for five consecutive hours. The greatest trouble appeared to be with the producer failing to work properly, it being apparently impossible to carry a load on the engine owing to lack of gas. Considerable trouble was also experienced from vibration and noise, due to the exhaust. This was so great that neighbors took legal steps to have the nuisance abated. The experiments finally culminated in a muffler exploding with considerable violence, thereby endangering the lives of those in the vicinity.

(*E*) This is an example of a producer plant apparently giving satisfaction. Few failures have occured and the costs are apparently moderate. In making up the costs, however, it could not be definitely determined what load the plant was carrying, hence, a value had to be assumed, and, as usual, the greatest value consistent with facts was taken. It is therefore more than possible that the values of costs here given are too low.

(*F*) This is another example of a gas engine giving satisfaction. The owners have made a careful study of gas producer plants, and their marked success is no doubt due to this fact. They have had their producer built according to their own design and under their own supervision, and this has brought the cost to a minimum for this part of the equipment, as the time spent by themselves in designing and supervising has not been charged. A very high load factor has also been taken for the plant.

(*G*) This plant is chiefly interesting as it is a plant owned by a firm interested in the gas producer business. They exhibit this plant as an example of reliability and economy, but admit that failures have occured through improper ignition. To secure the results obtained, they have found it advisable to use a special grade of coal and pay 11 per cent. more for it than the usual run of pea anthracite.

(*H*) This plant is also owned by people interested in the business. The plant was not visited, but the exact figures supplied by

the owners have been used in making up the estimate. The only items which could not be secured are the cost of the plant and the amount of water used. It will be seen, however, that low values have been taken for both these items. Stops averaging 15 minutes each time are said to occur about once a week. In this case the fuel used is coke, and it is said to give very good satisfaction.

SUMMARY.

The system of accounting as employed by small users of power has no doubt led to the impression that the gas producer engine is about to become the chief means of securing power in progressive manufacturing establishments. Costs of attendance and fuel are considered to be the only factors worthy of consideration when comparing the economic value of different prime movers. The charges against capital, repairs, failures of power and numerous minor expenses are usually placed in the background or entirely overlooked. The question of load factor is also little understood by the average power user. Costs are usually based on the full load conditions, which, in the ordinary factory, obtain for only a short time, while for the remainder of the day a very much smaller load is being carried. In the majority of cases, the average day load throughout the year is less than half of the maximum for that year. The overload capacity of the average gas engine is almost nothing. In buying an engine, some margin must of necessity be left for unusually busy days, for a poorer grade of coal than the ordinary and for at least some slight addition to the load in the future, hence, the gas engine in the ordinary factory is compelled to carry an average load of less than one-half its rated capacity. (This statement would be considered erroneous by the majority of people, but it is nevertheless true.)

There are some special cases where the load can be maintained almost constant for the whole year, but these are very exceptional. It follows, therefore, that the average gas power user is paying for his power just double what he considers to be the case. This neglect of considering the effect of load factor on the costs has led, more than anything else, to an optimistic view of the gas producer question.

Another erroneous impression which the public appears to hold is that a small gas producer (since it requires no smoke stack) may be placed in almost any part of a building without bad results. In reality, the location for a producer plant should be selected with even greater care than for a steam engine, as the question of ventilation is of great importance. The exhaust is more troublesome than that from a steam engine, owing to the quantity of gas emitted and

the noise. The gas plant is admitted to be less reliable, so far as continuity of service is concerned, than the steam engine.

A small gas plant, however, has the advantages over steam, in so far that no black smoke is emitted, costs for fuel and attendance are less, and also the total yearly costs, and the plant may be started, everything being cold, more quickly than the steam plant.

The gas plant may be used to good advantage where continuity of service is not of prime importance and where electric power cannot be obtained or where the cost of such power is excessive. The costs of producer power are much greater than usually given. These costs are usually based on a test carefully made under full load conditions. Figures received from the users of producer power usually omit fixed and other important charges, and are almost invariably based on the assumption that the average yearly load is approximately equal to the maximum load carried.

(Sgd.) F. T. S.

APPENDIX II.

REPORT OF MR. STERN.

Toronto, February, 1908.

P. W. Sothman, Esq.,

Chief Engineer, Hydro-Electric Power Commission, Toronto:

Dear Sir:—

I beg to submit, herewith, report on 24 gas producer plants, inspected by me in the Eastern States, in accordance with your order.

This report in general has been largely influenced by the present financial stringency, which has resulted in a general industrial breakdown.

According to the information received, many plants only carried a small percentage of their rated capacity, owing to the fact that large portions of the works were closed down. Other factories have only worked part of the time, thus reducing the output. However, in every case, I have endeavored to get the figures approximating ordinary conditions. All the plants inspected were in large cities, and I found that 12 out of 23 had auxiliary city gas installed, mainly for small units.

Below, I beg to make the following remarks with reference to the individual plants:—

1. This is a plant where a selling concern has used the customer for the purposes of experiment. The plant was installed two years ago for generating electricity, but has never given satisfaction, and has been out of use for the last six months, owing to the fact that the Electric Light Co. of the city reduced their rate from eight cents to four and one-half cents per K.W. Frequent breakdowns and interruptions in the service have been the main cause for its abandonment.

2. A very complete suction plant giving reliable service. A large portion of the producer gas is used successfully for soldering furnaces, and heating a lime kettle. This plant has been in operation for nine months, for power and lighting, and is highly recommended by the user.

5. Pressure producer, driving gas engine for electric power and light in dye works in ————. This plant has been in use for four and a half years, the larger engine being installed two

years ago, the old engine being used as a standby. Producer gas is also used for 250 ironing stoves. This plant gives reliable service.

6. A pressure producer gas plant for power and electric lighting. The plant, which was installed in the basement of the building, has been in use for one year, and gives reliable service. There is complaint about the odor of gas in the building, due to the pressure type of plant.

7. A new plant, installed in a chemical works for an electrolytic process, of two engines directly connected to electric generators which run practically the whole year round, with a perfectly stead load. This plant is not in continuous use at the present time, owing to the lack of work.

8. This installation is used for electric power and heating in a sheet metal works in the City of ————. It has been in successful operation for fifteen months. Electric drive is used throughout the factory. Fifty soldering furnaces, two large zinc smelting furnaces and one annealing oven are heated by producer gas. City gas was formerly used for heating, amounting to a total cost of over $100 per month.

9. Two gas engines driving one line shaft for power and light. Two steam engines take the balance of the load; the gas plant is in steady use and steam engines are used for the overload only. The plant has been in use for three years, and is giving reliable service. This plant is also installed in a dark and inferior position in the basement.

10. Small suction producer plant installed in a dark, close basement, working under most unfavorable conditions, with the smallest amount of attendance and apparently neglected. The plant is not absolutely reliable, but is still giving satisfaction to the owner. It has been in operation for a year and a half, and is used for power only.

11. One thousand horse power pressure producer, largely used for making water gas for nineteen forge fires. Producer gas is a by-product used for gas engines, generating electric power and light, giving reliable service and has been in use for three years.

12. This is a suction gas producer plant for electric power and light, installed in the basement of a factory building near New York. It has been in use for one year, giving reliable service, and seems to be a model plant, giving every satisfaction. A small amount of gas is used for fuel.

13. A suction-pressure gas plant, for electric power and light, installed in a machine shop near New York City. It has been in use for sixteen months, giving reliable service, and is a model plant.

14. A pressure producer plant for electric power and light, for tube work, near ———. It has been in use four and a half years, and gives reliable service. The plant is being changed at present from pressure to suction system, and a new producer is being installed, the old producer will be used for making fuel gas.

15. This is a new installation which has been in service for only four months, and has given satisfaction since starting. It is used for power and electric light in a chocolate factory near New York. Reliable service and low attendance are its main features. City gas was formerly the motive power. The gas producer has been installed in the yard and is without building. The engine is in an inferior location in the basement.

16. This is one of the oldest plants on the continent, having eight engines of various capacities and make, supplied by two large pressure gas producers. The plant is used principally for lighting a terminal railway station and for driving air and Pintseh gas compressors. In this case the fullest reliability is necessary, still there are no spare engines, the plant being worked at full capacity during the night. The plant, which has been in operation for nine years, was enlarged about two years ago, and, although it is not up-to-date, and has no auxiliary available, shut-downs seem to be an unknown quantity.

17. This plant is another failure. A concern which was well known for building city gas, natural gas and gasoline engines, used this manufacturer, two years ago, for their first experiment with a suction gas plant. The plant was a total failure and was taken out after three months' experimenting. No expense resulted to the party for whom the plant was installed.

18. Incompetent men advised and installed a suction gas plant, without any experience in the business. Naturally, the plant was a total failure and was taken out without ever having done any service.

19. A gasoline engine about twelve years old. This engine has been used with city gas for the last year, but within the last three weeks, it has been connected with a suction gas producer. The attendants have not become accustomed to the new arrangement, and the engine is not as yet properly adjusted for the new system, so that stoppages are quite frequent. The user who supplies his own ma-

chine shop and a five story factory building with electric power and light, has full confidence in its final success. The figures given in the table show plainly that conditions are not, at present, satisfactory, and they cannot be considered as definite.

20. This is a pressure producer installed in a large machine shop of gas engine builders. Gas is used for power, annealing ovens, soldering torches and testing gas engines. Engines have been in use one year and a half for electric power and lighting.

23. This is a very delicate plant to handle. The producer is not reliable, and city gas has frequently to be used for a short period, while new gas is being made in the producer. The producer manufacturer is experimenting. The owner has confidence in its final success.

24. A well installed and operated suction producer plant driving a machine shop. The plant gives reliable service, and is highly recommended by the user. It has been in operation for two years for a power and lighting service. City gas used for twenty minutes every morning to blow up the fire in the producer.

25. This suction gas plant has been in operation for nine months and is used for supplying power to an air compressor and a small electric generator, which are belt driven. There has been no interruption in the service and it is giving the user full satisfaction. The plant is used twenty-four hours per day for about six months in the year. There are two producers installed, one acting as a standby.

26. A well installed and carefully operated suction producer plant, operating belt-driven air compressors and electric generator. The service has been reliable. One of the three engines and one producer are held in reserve.

27. A new suction producer and engine direct-connected to 125 K.W. generator, installed to operate in conjunction with steam electric plant previously in operation. It would seem that this plant has not been properly installed and that the attendants have not yet become accustomed to the new system, and as a result, frequent stoppages and delay are the consequences. In this case, as in most similar ones, the user is confident of the ultimate success of the plant.

28. The first engines of this plant were installed to work with illuminating gas. About two years ago, two pressure producers were connected to the same and the capacity was increased by the addition of a 250 H.P. engine, direct-connected to electric generator. The

number of units installed permits of great flexibility in operation and consequently the service has been practically continuous. This plant operates in conjunction with a steam-driven electric plant.

Summary.

In obtaining information the principal object was to find out what the users of producer plants are really doing, and also to allow the public to pass its own judgment on this question, enabling them to make proper comparisons between the figures offered by gas producer plant manufacturers and those offered by concerns supplying power by other means.

Up to the present time it is impossible to pass a final opinion regarding producer gas, gas producers and producer gas engines. Producer gas cannot be declared a complete success because many plants do not give satisfaction and are unreliable and expensive to operate, on account of high oil and water consumption, high wages, repairs, and capital cost. But producer gas cannot be considered a total failure because many plants have been in successful operation for years, they are absolutely reliable, the attendance, repair, fuel, water and oil consumption being low.

The reason for the partial or total failure of producer gas plants will always be found due to a lack of knowledge and experience. This lack of knowledge and experience may generally be ascribed to ignorance in the design, building, installation and operation. None of these instances have come down to a standard in Canada and the United States, and ignorance of one of these four points, is sufficient, of course, to make a gas producer plant a failure. In most cases where plants have been bought of and installed by a reliable concern, they will work satisfactorily providing that an intelligent and reliable man is in charge of same. This last point is essential to the success of a producer gas plant.

It is generally claimed by the manufacturer of gas producer plants and engines that no mechanic or licensed engineer is required to run the same. This is true to a certain extent, and I have found in several cases a plant in successful operation being run by a man who had no mechanical knowledge whatever. In one case a man was found in charge of the heating, boiler, gas and electric plant, who had changed from a horse driver to an engine driver over night. The manager of the factory stated that this man replaced a licensed steam engineer, who was not able to manage this plant at all, and in consequence of the change, the fuel consumption had been reduced from

six tons a week to three tons a week, for the reason that the steam engineer used to draw the fire as in a boiler, thus wasting half of the fuel. The fact that this firm had a licensed engineer, who was a high salaried man, shows that this change was not due to any financial consideration, it simply shows that the right class of men are not generally available to run gas producer plants.

General experience goes to show that in most cases a green man does better work than an old steam engineer.

In many cases manufacturers have abused their customers by doing the experimenting for them at the customer's expense. This has certainly done harm, not only to the experimenting party, but to the whole trade. In other cases it is impossible to do all the experimenting at home, for instance, if a Steel Company orders a 2,000 H.P. engine for blast furnace gas, it is impossible to try it in the shop, and the manufacturer should not be blamed if it takes some time to get the engine into proper shape.

Generally speaking, producer gas is being introduced slowly but steadily. Like every new thing, it requires time for development, and we may trust that it will shortly be allowed to take its part in Canada's power generation as it already does in England and other European countries, helping to increase the industry and manufacturing capacity of our country.

In conclusion, I take this opportunity to thank all the gentlemen who have so freely given information, and who were material in making this report complete.

Yours truly,

(Sgd.) EMIL. STERN.

Asst. Engineer.